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VENTILATORY THRESHOLDS DURING A GRADED EXERCISE TEST: THE EFFECTS OF THREE TRAINING INTENSITIES IN MALES

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Ventilatory Thresholds During A Graded Exercise Test: The Effects of Three Training Intensities in Males" submitted by Yagesh Bhambhani in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Physical Education.

ABSTRACT

Forty male volunteers participated in a graded exercise test on a bicycle ergometer on three occasions. In each case two distinct ventilatory thresholds were detected by monitoring selected respiratory gas exchange variables prior to reaching the Maximum Exercise Capacity (MEC). The first threshold, termed Threshold One (Th.1) in this study, was characterized by the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio and the F_EO_2 reached a minimum. At power outputs above this threshold the $\dot{V}_E/\dot{V}O_2$ ratio increased continuously indicating a hyperventilation with respect to oxygen consumption. The second threshold, termed Threshold Two (Th.2) in this study, was characterized by the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum and the F_ECO_2 reached a maximum. At power outputs above this threshold the $\dot{V}_E/\dot{V}CO_2$ ratio increased continuously indicating a hyperventilation with respect to carbon dioxide production.

Correlations computed for the power output, time, ventilation volume, absolute oxygen consumption, relative oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio between each of these thresholds and the MEC indicated that the values at Th.2 were more closely related to the MEC than those at Th.1. Also, the correlations between the two thresholds for these variables were significant in most cases.

After blocking the forty subjects into high and low fit categories on the basis of their relative maximum oxygen uptakes, significantly higher relative oxygen uptakes at Th.1 and Th.2 were observed in the high fit category when compared to the low fit category. At the MEC, the $\dot{V}_E/\dot{V}O_2$ ratio was significantly lower in the high fit category on two of the

three test trials.

To study the effects of training on these two thresholds, the subjects in each fitness category were assigned to one of the following groups : (1) a Control Group (CG) which did not train (2) a Threshold Group (TG) which trained at an oxygen consumption that was approximately ten percent above that at Th.1 (3) an Above Threshold Group (ATG) which trained at an oxygen consumption that was approximately fifty percent between that at Th.1 and the maximum oxygen uptake and (4) an Interval Training Group (ITG) which trained at one-hundred percent of the maximum oxygen uptake with work:rest intervals of one minute each. In each of the twenty-four training sessions completed, the total work done by the experimental groups was equalized. The results indicated that both the fitness categories responded similarly to the treatments. All three training groups showed a significant increase in the power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption at Th.1, Th.2 and the MEC, except the ITG which showed no significant increase in the absolute or relative oxygen consumption at Th.1. The $\dot{V}_E/\dot{V}O_2$ ratio showed no significant change at Th.1 and at the MEC, while at Th.2 it increased significantly in the ATG and ITG. At the pre training MEC power output, significant decreases in the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ ratios were observed in all three training groups. The decrease in these ratios was attributed primarily to a significant decrease in the ventilation volume indicating a decreased ventilatory drive as a result of training.

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	STATEMENT OF THE PROBLEM	1
	Introduction	1
	The Problem	2
	Hypotheses	4
	Limitations of the Study	6
	Delimitations of the Study	6
	Definition of Terms	6
II.	REVIEW OF LITERATURE	8
	The Concept of the Anaerobic Threshold	8
	Detection of the Anaerobic Threshold	10
	(1) Invasive Techniques	10
	(2) Non-Invasive Techniques	11
	Factors Affecting the Accuracy of the Anaerobic Threshold	13
	(1) Hyperventilation	13
	(2) Blood Temperature	14
	(3) Oxymyoglobin Stores	14
	(4) Substrate Concentration	15
	(5) Mode of Exercise	15
	(6) Duration of Exercise at Each Intensity	16
	(7) Pedaling Speed	17
	Validity of the Anaerobic Threshold	17
	Reliability of the Anaerobic Threshold	19
	(1) Test-Retest Reliability	19
	(2) Inter-Tester Reliability	21

CHAPTER PAGE

Values of the Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature.. 22

Physiological Factors Influencing the Anaerobic Threshold.. 22

(1) Age...................................... 22

(2) Sex...................................... 22

(3) Fibre Type............................... 27

(4) Enzyme Activities........................ 30

(5) Menstrual Cycle.......................... 31

Effect of Physical Training on the Anaerobic Threshold.. 31

(1) The Relationship between the Oxygen Consumption at the Anaerobic Threshold and the Maximum Oxygen Uptake.................... 31

(2) Training Studies......................... 33

Significance of the Anaerobic Threshold........... 36

(1) Ability to Perform at a Higher Exercise Intensity................................... 36

(2) Ability to Perform for Prolonged Periods. 37

(3) Ability to Perform at a Lower Oxygen Cost 38

Controversy Regarding the Use of the Term Anaerobic Threshold.. 38

The Threshold of Decompensated Metabolic Acidosis.. 39

III. METHODS AND PROCEDURES................................. 43

Subjects.. 43

Anthropometric Data................................. 43

The Beckman Metabolic Measurement Cart (MMC)....... 43

CHAPTER PAGE

(1) Description.............................. 43

(2) Calibration.............................. 44

Preliminary Testing.............................. 44

(1) Determination of the Anaerobic Threshold, Threshold of Decompensated Metabolic Acidosis and the Maximum Exercise Capacity............ 44

(2) Determination of Percent Body Fat......... 47

Assignment of Subjects to the Treatment Groups...... 47

The Training Program.............................. 48

Mid and Post Training Testing...................... 50

Experimental Design.............................. 50

Statistical Analysis.............................. 52

IV. RESULTS.............................. 53

SECTION A.............................. 53

Characteristics of the Subjects.................... 53

Assignment of the Subjects to the Treatment Groups.. 56

Attrition Rate.............................. 56

SECTION B.............................. 60

The $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio, F_EO_2, F_ECO_2, Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test.................... 60

SECTION C.............................. 69

Inter-relationship between the Selected Variables at: 70

(1) The Maximum Exercise Capacity............ 70

(2) Threshold One.............................. 70

(3) Threshold Two.............................. 70

CHAPTER PAGE

Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Selected Variables.... 80

(1) Power Output.... 80

(2) Time.... 80

(3) Ventilation Volume.... 83

(4) Absolute Oxygen Consumption.... 83

(5) Relative Oxygen Consumption.... 83

(6) $\dot{V}_E/\dot{V}O_2$ Ratio.... 83

SECTION D.... 88

Interpretation of the Three-Way Analysis of Variance.... 88

Comparison between the High and Low Fit Categories on the Pre, Mid and Post Tests for the Selected Variables at: 90

(1) The Maximum Exercise Capacity.... 90

(2) Threshold One.... 92

(3) Threshold Two.... 92

The Effect of the Four Treatments on the Selected Variables at: 97

(1) The Maximum Exercise Capacity.... 97

(2) Threshold One.... 97

(3) Threshold Two.... 97

Effect of the Four Treatments on the Ventilation Volume, Oxygen Consumption, Carbon Dioxide Production, $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio and F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output.... 101

V. DISCUSSION.... 105

SECTION A.... 105

CHAPTER PAGE

Characteristics of Subjects in the Fitness Categories and Treatment Groups...................... 105

SECTION B... 106

Comparison of the $\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$, F_EO_2 and F_ECO_2 Curves between Subjects................................ 106

Significance of the Relationship between the $\dot{V}_E/\dot{V}O_2$ Ratio and the F_EO_2.......................... 109

Significance of the Relationship between the $\dot{V}_E/\dot{V}CO_2$ Ratio and the F_ECO_2........................ 110

Increases in the Ventilation Volume at Threshold One and Threshold Two................................. 114

Values of the Selected Variables at Thresholds One and Two.. 118

(1) Threshold One............................. 118

(3) Threshold Two............................. 120

SECTION C 121

Inter-relationship between the Selected Variables at: 121

(1) The Maximum Exercise Capacity............. 121

(2) Threshold One............................. 124

(3) Threshold Two............................. 125

Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Selected Variables.. 125

SECTION D 128

Comparison between the High and Low Fit Categories for the Selected Variables at: 128

(1) The Maximum Exercise Capacity............. 128

(2) Threshold One............................. 129

(3) Threshold Two............................. 130

Comments on the Training Program..................... 132

CHAPTER PAGE

Effect of the Four Treatments on the Selected Variables at: 134

(1) The Maximum Exercise Capacity........... 134

(2) Threshold One........................... 137

(3) Threshold Two........................... 145

Effect of the Four Treatments on the Ventilation Volume, Oxygen Consumption, Carbon Dioxide Production, $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio and F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output.. 150

VI. SUMMARY AND CONCLUSIONS................................ 156

Summary.. 156

Conclusions...................................... 158

Recommendations.................................. 169

BIBLIOGRAPHY.. 161

APPENDIX A Consent Form, Instructions to Subjects........... 172

APPENDIX B Data Collection Sheets............................ 175

APPENDIX C Raw Data (Tables 34-68)........................... 181

APPENDIX D Summaries of Analyses of Variance (Tables 69-121). 217

LIST OF TABLES

TABLE		PAGE
1	Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature...	23
2	Correlation Coefficients between the Oxygen Consumption at the Anaerobic Threshold and the Maximum Oxygen Uptake reported in the Literature..	34
3	Method of Equating the Total Amount of Work Done Per Training Session..............................	51
4	Characteristics of High and Low Fit Subjects......	54
5	Assignment of Subjects to the Treatment Groups by the Technique of Stratified Randomization......	57
6	Pre Training Comparisons of Selected Variables at the Anaerobic Threshold and Maximum Exercise Capacity in the High and Low Fit Categories.......	59
7	Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Pre Test..	71
8	Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Mid Test..	72
9	Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Post Test.	73
10	Inter-relationship between the Selected Variables at Threshold One on the Pre Test.................	74
11	Inter-relationship between the Selected Variables at Threshold One on the Mid Test.................	75
12	Inter-relationship between the Selected Variables at Threshold One on the Post Test................	76
13	Inter-relationship between the Selected Variables at Threshold Two on the Pre Test.................	77
14	Inter-relationship between the Selected Variables at Threshold Two on the Mid Test.................	78
15	Inter-relationship between the Selected Variables at Threshold Two on the Post Test................	79
16	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the	

TABLE		PAGE
	Power Output on the Pre, Mid and Post Tests.......	81
17	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Time on the Pre, Mid and Post Tests...............	82
18	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Ventilation Volume on the Pre, Mid and Post Tests.	84
19	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Absolute Oxygen Consumption on the Pre, Mid and Post tests..	85
20	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Relative Oxygen Consumption on the Pre, Mid and Post Tests..	86
21	Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the $\dot{V}_E/\dot{V}O_2$ Ratio on the Pre, Mid and Post Tests.......	87
22	Comparison between the High and Low Fit Categories for the Selected Variables at the Maximum Exercise Capacity on the Pre, Mid and Post Tests...........	91
23	Comparison between the High and Low Fit Categories for the Selected Variables at Threshold One on the Pre, Mid and Post Tests..........................	93
24	Comparison between the High and Low Fit Categories for the Selected Variables at Threshold Two on the Pre, Mid and Post Tests..........................	94
25	Comparison between the High and Low Fit Categories for the Selected Variables at Threshold One expressed as a Percentage of the Maximum Exercise Capacity on the Pre, Mid and Post Tests...........	95
26	Comparison between the High and Low Fit Categories for the Selected Variables at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity on the Pre, Mid and Post Tests...........	96
27	Effect of the Four Treatments on the Selected Variables at the Maximum Exercise Capacity in the High and Low Fit Categories Combined.............	98

TABLE		PAGE
28	Effect of the Four Treatments on the Selected Variables at Threshold One in the High and Low Fit Categories Combined	99
29	Effect of the Four Treatments on the Selected Variables at Threshold Two in the High and Low Fit Categories Combined	100
30	Effect of the Four Treatments on the Selected Variables at Threshold One expressed as a Percentage of the Maximum Exercise Capacity in the High and Low Fit Categories Combined	102
31	Effect of the Four Treatments on the Selected Variables at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity in the High and Low Fit Categories Combined	103
32	Effect of the Four Treatments on the Ventilation Volume, Oxygen Consumption, Carbon Dioxide Production, $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio and F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output	104
33	Means, Standard Deviations and Ranges of the Selected Variables at Threshold One and Threshold Two observed in this Study	119
34	Raw Data for One Subject	182
35	Power Output at the Maximum Exercise Capacity	183
36	Time at the Maximum Exercise Capacity	184
37	Ventilation Volume at the Maximum Exercise Capacity	185
38	Absolute Oxygen Consumption at the Maximum Exercise Capacity	186
39	Relative Oxygen Consumption at the Maximum Exercise Capacity	187
40	$\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity	188
41	Power Output at Threshold One	189
42	Time at Threshold One	190
43	Ventilation Volume at Threshold One	191

TABLE PAGE

44 Absolute Oxygen Consumption at Threshold One..... 192

45 Relative Oxygen Consumption at Threshold One..... 193

46 $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One.................... 194

47 Power Output at Threshold Two.................... 195

48 Time at Threshold Two............................ 196

49 Ventilation Volume at Threshold Two.............. 197

50 Absolute Oxygen Consumption at Threshold Two..... 198

51 Relative Oxygen Consumption at Threshold Two..... 199

52 $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two.................... 200

53 Power Output at Threshold One expressed as a Percentage of the Power Output at the Maximum Exercise Capacity................................. 201

54 Time at Threshold One expressed as a Percentage of the Time at the Maximum Exercise Capacity..... 202

55 Ventilation Volume at Threshold One expressed as a Percentage of the Ventilation Volume at the Maximum Exercise Capacity........................ 203

56 Oxygen Consumption at Threshold One expressed as a Percentage of the Oxygen Consumption at the Maximum Exercise Capacity........................ 204

57 $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One expressed as a Percentage of the $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity................................. 205

58 Power Output at Threshold Two expressed as a Percentage of the Power Output at the Maximum Exercise Capacity................................. 206

59 Time at Threshold Two expressed as a Percentage of the Time at the Maximum Exercise Capacity..... 207

60 Ventilation Volume at Threshold Two expressed as a Percentage of the Ventilation Volume at the Maximum Exercise Capacity........................ 208

61 Oxygen Consumption at Threshold Two expressed as a Percentage of the Oxygen Consumption at the Maximum Exercise Capacity........................ 209

TABLE		PAGE

62	$\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two expressed as a Percentage of the $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity..................................	210
63	Ventilation Volume at the Pre Training Maximum Exercise Capacity Power Output...................	211
64	Oxygen Consumption at the Pre Training Maximum Exercise Capacity Power Output...................	212
65	Carbon Dioxide Production at the Pre Training Maximum Exercise Capacity Power Output...........	213
66	$\dot{V}_E/\dot{V}O_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output.............................	214
67	$\dot{V}_E/\dot{V}CO_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output...................	215
68	F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output.............................	216
69	Summary of Analysis of Variance: Age of High and Low Fit Categories................................	218
70	Summary of Analysis of Variance: Height of High and Low Fit Categories..........................	218
71	Summary of Analysis of Variance: Weight of High and Low Fit Categories..........................	218
72	Summary of Analysis of Variance: Percent Body Fat of High and Low Fit Categories...............	218
73	Summary of Analysis of Variance: Pre Training Absolute Maximum Oxygen Consumption of the High and Low Fit Categories..........................	218
74	Summary of Analysis of Variance: Pre Training Relative Maximum Oxygen Consumption of the High and Low Fit Categories.........................	218
75	Summary of Analysis of Variance: Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of the High and Low Fit Categories....	219
76	Summary of Analysis of Variance: Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of the High and Low Fit Categories....	219
77	Summary of Analysis of Variance: Pre Training	

TABLE		PAGE

	Relative Maximum Oxygen Consumption of Treatment Groups in the High Fit Category................	219
78	Summary of Analysis of Variance: Pre Training Relative Maximum Oxygen Consumption of Treatment Groups in the Low Fit Category.................	219
79	Summary of Analysis of Variance: Pre Training Absolute Maximum Oxygen Consumption of Treatment Groups in the High Fit Category................	219
80	Summary of Analysis of Variance: Pre Training Absolute Maximum Oxygen Consumption of Treatment Groups in the Low Fit Category.................	219
81	Summary of Analysis of Variance: Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the High Fit Category.......................................	220
82	Summary of Analysis of Variance: Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the Low Fit Category.......................................	220
83	Summary of Analysis of Variance: Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the High Fit Category.......................................	220
84	Summary of Analysis of Variance: Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the Low Fit Category.......................................	220
85	Summary of Analysis of Variance: Pre Training Power Output at the Anaerobic Threshold of Treatment Groups in the High Fit Category.......	220
86	Summary of Analysis of Variance: Pre Training Power Output at the Anaerobic Threshold of Treatment Groups in the Low Fit Category........	220
87	Critical 'F' Ratios for Significance on the Analysis of Variance and the Greenhouse-Geisser Conservative Test..............................	221
88	Summary of Analysis of Variance: Power Output at the Maximum Exercise Capacity...............	222
89	Summary of Analysis of Variance: Time at the Maximum Exercise Capacity......................	222

TABLE		PAGE
90	Summary of Analysis of Variance: Ventilation Volume at the Maximum Exercise Capacity..........	222
91	Summary of Analysis of Variance: Absolute Oxygen Consumption at the Maximum Exercise Capacity.....	223
92	Summary of Analysis of Variance: Relative Oxygen Consumption at the Maximum Exercise Capacity.....	223
93	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity....................	223
94	Summary of Analysis of Variance: Power Output at Threshold One..................................	224
95	Summary of Analysis of Variance: Time at Threshold One......................................	224
96	Summary of Analysis of Variance: Ventilation Volume at Threshold One..........................	224
97	Summary of Analysis of Variance: Absolute Oxygen Consumption at Threshold One.....................	225
98	Summary of Analysis of Variance: Relative Oxygen Consumption at Threshold One.....................	225
99	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One......................................	225
100	Summary of Analysis of Variance: Power Output at Threshold Two......................................	226
101	Summary of Analysis of Variance: Time at Threshold Two......................................	226
102	Summary of Analysis of Variance: Ventilation Volume at Threshold Two..........................	226
103	Summary of Analysis of Variance: Absolute Oxygen Consumption at Threshold Two.....................	227
104	Summary of Analysis of Variance: Relative Oxygen Consumption at Threshold Two.....................	227
105	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two......................................	227
106	Summary of Analysis of Variance: Power Output at Threshold One expressed as a Percentage of the Maximum Exercise Capacity........................	228

TABLE		PAGE
107	Summary of Analysis of Variance: Time at Threshold One expressed as a Percentage of the Maximum Exercise Capacity........................	228
108	Summary of Analysis of Variance: Ventilation Volume at Threshold One expressed as a Percentage of the Maximum Exercise Capacity.................	228
109	Summary of Analysis of Variance: Oxygen Consumption at Threshold One expressed as a Percentage of the Maximum Exercise Capacity......	229
110	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One expressed as a Percentage of the Maximum Exercise Capacity........................	229
111	Summary of Analysis of Variance: Power Output at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity........................	229
112	Summary of Analysis of Variance: Time at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity........................	230
113	Summary of Analysis of Variance: Ventilation Volume at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity.................	230
114	Summary of Analysis of Variance: Oxygen Consumption at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity......	230
115	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity........................	231
116	Summary of Analysis of Variance: Ventilation Volume at the Pre Training Maximum Exercise Capacity Power Output...........................	231
117	Summary of Analysis of Variance: Absolute Oxygen Consumption at the Pre Training Maximum Exercise Capacity Power Output...........................	231
118	Summary of Analysis of Variance: Carbon Dioxide Production at the Pre Training Maximum Exercise Capacity Power Output...........................	232
119	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output..	232

TABLE		PAGE
120	Summary of Analysis of Variance: $\dot{V}_E/\dot{V}CO_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output....................................	232
121	Summary of Analysis of Variance: F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output..	233

LIST OF FIGURES

FIGURE		PAGE
1	Subject in the Appropriate Testing Position........	46
2	The Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for One Subject..............	61
3	The Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for the Sample of Thirty-Eight Subjects..	62
4	The Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for One Subject...........	64
5	The Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for the Sample of Thirty-Eight Subjects....................................	65
6	The Pre Training Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test for One Subject....................................	66
7	The Pre Training Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test for the Sample of Thirty-Eight Subjects...........	67
8	Relationship between the Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for One Subject..	111
9	Relationship between the Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for the Sample of Thirty-Eight Subjects..................	112
10	Relationship between the Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for One Subject..	115
11	Relationship between the Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for the Sample of Thirty Eight Subjects..................	116
12	The Effect of Training on the Power Output and $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One for One Subject......	141
13	The Effect of Training on the Power Output at Threshold Two for One Subject.......................	146
14	The Effect of Training on the $\dot{V}_E/\dot{V}O_2$ Ratio for the Subjects in the Above Threshold Group (Low Fit)....	151

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The Anaerobic Threshold (AT) has been defined as the lowest oxygen uptake or power output at which the level of lactic acid in the blood increases to a level that is significantly higher than that observed at rest (66, 90, 110). Since the accumulation of lactic acid within the muscle cell is one of the primary metabolic factors associated with muscular fatigue (124), it is imperative that individuals who wish to perform successfully in endurance events have high ATs. Some researchers (15, 17, 19, 22, 135) have suggested that differences in endurance performance between individuals with similar maximum oxygen uptakes could be due to their differences in the AT, while others (22) believe that improvements in endurance performance of elite athletes subsequent to training which does not result in a significant improvement in the maximum oxygen uptake may be due to an improvement in the AT.

In the mid sixties, Wasserman and co-workers (113, 116) coined the term 'Anaerobic Threshold' and suggested a non-invasive technique by which this exercise intensity could be detected. They were able to demonstrate that during a graded exercise test, the oxygen consumption or power output at which: (1) the volume of carbon dioxide produced per minute ($\dot{V}CO_2$) (2) the volume of air expired per minute ($\dot{V}_E$) and (3) the respiratory exchange ratio (R) increased non-linearly corresponded

to the exercise intensity at which the concentration of lactic acid in the blood was significantly above resting levels - i.e. the AT. Since the initial work done by these researchers, several studies (22, 24, 90-92, 121, 123) have confirmed that the AT could be detected via selected respiratory gas exchange measurements and in the process have established its validity and reliability.

<u>The Problem</u>

Recent research in the area of exercise physiology suggests that two metabolic thresholds exist during a graded exercise test, both of which could be detected non-invasively by continuously monitoring selected respiratory gas exchange variables. Direct evidence was provided by Reinhard et al. (90) who observed that the lowest exercise intensity at which the concentration of lactic acid in the capillaries differed significantly from resting levels coincided with the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio reached its minimum value. This was the first threshold that these researchers detected and they termed it the 'Anaerobic Threshold' as was initially proposed by Wasserman et al (113,116). The second threshold that they observed was the exercise intensity at which the pH in the capillaries appeared to decrease significantly. This threshold, which they termed as the 'Threshold of Decompensated Metabolic Acidosis' (TDMA), could be detected by the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum. Both these thresholds were detected prior to the subject reaching the Maximum Exercise Capacity (MEC). Wasserman et al. (115) have also reported that the $\dot{V}_E/\dot{V}CO_2$ ratio begins to increase at a higher axercise intensity and lower pH than that at which the $\dot{V}_E/\dot{V}O_2$ ratio begins to increase

during a graded exercise test, results which seem to agree with those reported by Reinhard et al (90). Skinner and McLellan (101) as well as Kindermann et al. (64) have also suggested that two thresholds probably exist during a graded exercise test. Skinner and McLellan (101) indicate that the first threshold, which they suggest calling the 'Aerobic Threshold', could be detected by the exercise intensity at which the fraction of oxygen in the expired air (F_EO_2) begins to increase, along with a mild non-linear increase in the ventilation volume and volume of carbon dioxide produced. The second threshold, which they suggest calling 'Anaerobic Threshold', could be detected by the exercise intensity at which the fraction of carbon dioxide in the expired air (F_ECO_2) begins to decrease, along with a marked non-linear increase in the ventilation volume. One of the purposes of this study was to examine whether the AT and TDMA suggested by Reinhard et al. (90) coincided with the two thresholds suggested by Skinner and McLellan (101) in a group of male subjects. The inter-relationship between the AT, TDMA and the MEC was also studied for selected variables.

Several reports in the literature indicate that physical training, particularly of the endurance type (51, 52), increases the overall oxidative capacity of the skeletal muscle fibres which is reflected by an increase in the maximum oxygen uptake and a decrease in the lactic acid concentration at a given absolute (3, 29, 40, 45, 75, 93, 94) and relative (48, 49, 96, 130) submaximal power output. Theoretically, an increase in the oxidative capacity of the skeletal muscle fibres should delay the exercise intensity at which the lactic acid concentration increases significantly (i.e. the AT) as well as the exercise intensity

at which the pH decreases significantly (i.e. the TDMA). Research that has been done to study the effect of physical training on these two thresholds is minimal. Studies have indicated that the oxygen consumption at the AT could be significantly increased by continuous training if the intensity was considerably above this value (22, 92, 94, 98, 130). However, if the training intensity was below this value, no significant change in this variable was observed (92). Hence, the minimal training intensity(ies) for bringing about significant changes in the oxygen consumption at these two thresholds has not yet been established. Also, the effect of interval training on these two thresholds is unknown. Since this method of training is capable of inducing significant increases in the maximum oxygen uptake as well as reducing blood lactate concentrations at a given submaximal power output (29, 37-40, 67), it is possible that it will elicit significant improvements in the oxygen consumptions at both these thresholds. Other purposes of this study, therefore, were to: (1) determine whether there were any significant differences between a group of high and low fit male subjects for selected variables at the AT and TDMA (2) study the effects of three different instensities of physical training on the selected variables at these two thresholds and (3) examine whether the three different training intensities had a differential effect on the selected variables at the two thresholds in the high and low fit categories.

Hypotheses

The following hypotheses were examined in this study:

1) Two distinct thresholds, namely the AT and TDMA, would be detected during the graded exercise test prior to reaching the MEC.

2) No significant inter-relationship would be observed between the AT, TDMA and MEC for any of the variables selected at these three reference points.

3) No significant differences between the two fitness categories would be observed for the variables selected at the AT and TDMA.

4) There would be no significant differences between the three training intensities in the changes in any of the variables selected at the AT and TDMA.

5) There would be no significant difference between the two fitness categories for any changes observed at the AT and TDMA as a result of the three training intensities.

The following variables were selected at each of these three reference points: (1) power output, KPM/min (2) time, mins (3) ventilation volume, ml/min BTPS (4) absolute oxygen consumption, ml/min STPD (5) relative oxygen consumption, ml/kg/min STPD and (6) $\dot{V}_E/\dot{V}O_2$ ratio.

Limitations of the Study

This study was subject to the following limitations:

1) Variations in the calibration of the metabolic cart, bicycle ergometer and other apparatus between testing sessions.

2) Diet and physical activity of the subjects immediately prior to testing which could have affected some of the variables being measured.

3) The decrease in maximum oxygen uptake which is known to occur with aging was not considered when the subjects were initially ranked on this basis and assigned to the training groups.

4) The 'shout' method of motivation was used for the testing and training sessions.

Delimitations of the Study

This study was subject to the following delimitations:

1) The participation of forty male volunteers whose characteristics are given in Table 4, pages 54 to 55.
2) The power output at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum corresponded to the AT, while that at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum corresponded to the TDMA.
3) The changes, if any, in the variables being studied were due to the physical training and not due to any other factors which could have affected them.

Definition of Terms

For the purpose of this study, the following definitions were appropriate.

Ventilatory Equivalent for Oxygen ($\dot{V}_E/\dot{V}O_2$) - the ratio between the volume of air expired ($\dot{V}_E$, ml/min BTPS) and the volume of oxygen consumed ($\dot{V}O_2$, ml/min STPD) at a given power output.

Ventilatory Equivalent for Carbon Dioxide ($\dot{V}_E/\dot{V}CO_2$) - the ratio between the volume of air expired ($\dot{V}_E$, ml/min BTPS) and the volume of carbon dioxide produced ($\dot{V}CO_2$, ml/min STPD) at a given power output.

Anaerobic Threshold (AT) - the exercise intensity at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum during a graded exercise test on a bicycle ergometer.

Threshold of Decompensated Metabolic Acidosis (TDMA) - the exercise intensity at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum during a graded exercise test on a bicycle ergometer.

Maximum Oxygen Uptake ($\dot{V}O_2$ max) - the maximum amount of oxygen that could be utilized (ml/min, STPD) during a graded exercise test on a bicycle ergometer.

Maximum Exercise Capacity (MEC) - the exercise intensity at which: (1) the maximum oxygen uptake was attained and/or (2) the subject was unable to continue exercising at the prescribed rate during a graded exercise test on a bicycle ergometer.

Maximum Ventilation Volume - the ventilation volume ($\dot{V}_E$, ml/min BTPS) attained at the MEC during a graded exercise test on a bicycle ergometer.

CHAPTER II

REVIEW OF LITERATURE

The Concept of the Anaerobic Threshold

During the course of a graded exercise test, there appears to be an exercise intensity at which the concentration of lactic acid that accumulates within the blood is significantly above that observed at rest (approximately 10 mg % or 1.1 mmols/litre). The oxygen uptake or the power output at this exercise intensity has been defined as the AT (66, 90, 113, 116). In the mid sixties, Wasserman and co-workers (113, 116) suggested a non-invasive technique for detecting the AT. These researchers observed that at a particular intensity of exercise the ventilation volume, volume of carbon dioxide produced and the respiratory exchange ratio increased non-linearly when they were monitored continuously during a graded exercise test. This intensity they felt corresponded to the AT because an analysis of the blood samples obtained during this test revealed that there was a concomittant: (1) increase in the blood lactate concentration (2) decrease in the blood bicarbonate concentration and (3) decrease in blood pH.

The explanation that these investigators offered for their conclusion was as follows. The lactic acid that had formed in the muscle cell during the graded exercise test diffused across the cell membrane into the blood where it was buffered predominantly by the bicarbonate buffer system according to Equation 1.

$CH_3CHOHCOOH + NaHCO_3 \rightarrow CH_3CHOHCOONa + H_2CO_3$ -------------- Eq. 1

Lactic Acid + Sodium Bicarbonate --> Sodium Lactate + Carbonic Acid

The carbonic acid that was formed was highly volatile and dissociated into water and carbon dioxide as shown in Equation 2, thereby increasing the partial pressure of carbon dioxide in the blood.

$H_2CO_3 \rightarrow H_2O + CO_2$ ------------------------------------ Eq. 2

Carbonic Acid --> Water + Carbon Dioxide

The non-linear increase observed in the ventilation volume was an attempt by the respiratory centre to compensate for the metabolic acidosis that resulted from the buffering of lactate in the blood. The non-linear increase in the volume of carbon dioxide produced was due to the combined effect of the hyperventilation and the higher levels of carbon dioxide (from lactate) in the blood. The non-linear increase in the the respiratory exchange ratio, the ratio between the carbon dioxide produced and oxygen consumed (measured at the lungs), was a consequence of the non-linear increase in the carbon dioxide production. The fact that there was no change in the value of the respiratory exchange ratio as long as the bicarbonate concentration was constant only reinforced their suspicion that the changes observed in the respiratory gas exchange variables were due to the changes occurring within the blood. Based on these observations, Wasserman et al. (120) defined the AT as the power output or oxygen consumption at which the ventilation

volume, volume of carbon dioxide produced and the respiratory exchange ratio increased non-linearly during a graded exercise test.

Detection of the Anaerobic Threshold

It is evident from the above discussion that the AT can be detected by invasive as well as non-invasive techniques.

(1) Invasive Techniques

The AT can be detected by analyzing blood samples for: (1) the lactate concentration (2) the bicarbonate concentration and (3) the pH. The AT is that exercise intensity at which the lactate concentration increases significantly and the arterial bicarbonate concentration and the pH begin to decrease. The changes in these blood parameters occur simultaneously, making it quite easy to detect the AT (113, 116). Some investigators have experienced difficulty in detecting the AT from blood lactate measurements only. For example, Stamford et al. (104) attempted to detect the AT by determining the intensity at which the venous blood lactate concentration increased significantly in response to a graded exercise test on a bicycle ergometer. Out of ten subjects performing one and two legged exercise, they were able to detect the AT in only sixty percent of the cases. In the remaining forty percent of the cases, the sharp increase in lactate concentration was not noticable. According to these researchers, this was most probably due to the inter-individual differences in: (1) the diffusion rate of lactic acid from the tissues into the blood (2) the buffering capacities and (3) the amount of fluid available for mixing with the lactate. Kindermann et al. (64) as well as Skinner and McLellan (101) have suggested that the oxygen uptake at which the

arterial blood lactate concentration rises to approximately 2 mmol/l from its resting value of approximately 1.1 mmol/l indicates the AT. This value, however, is not fixed and varies considerably between individuals.

(2) Non-invasive Techniques

(a) Using Respiratory Gas Exchange Measurements

The use of respiratory gas exchange measurements to detect the AT has become quite popular since the method was originally introduced by Wasserman and co-workers (113, 116, 120). Studies have since demonstrated that the ventilation volume seems to be the best single measure for detecting the AT while the least specific is the respiratory exchange ratio (24, 120). The latter is most probably due to the fact that the metabolic respiratory quotient (RQ) also increases as the work rate increases thereby making it difficult to detect the non-linear increase in the respiratory exchange ratio (120). Other criterion measures that have been used in conjunction with the above in order to make more accurate detections are:

(1) a decrease in the difference between the inspired and expired end tidal oxygen tensions along with no change in the difference between the inspired and expired end tidal carbon dioxide tensions (120). This is analagous to a systematic increase in the end tidal partial pressure of oxygen ($P_{ET}O_2$) with no change in the end tidal partial pressure of carbon dioxide ($P_{ET}CO_2$) (22). It should be noted that an increase in the former results in an increase in the fraction of oxygen in the expired air (F_EO_2) (22).

(2) the intensity at which the $\dot{V}_E/\dot{V}O_2$ ratio increases systematically (22) or reaches a minimum (90), without an increase in the $\dot{V}_E/\dot{V}CO_2$ ratio.

(b) Using Oxygen Uptake Kinetics

Whipp and Wasserman (128) have also used the oxygen uptake kinetics to detect the AT. They demonstrated that if the difference in the oxygen uptake between the third and sixth minute of a constant work load test was not a finite value, then the workload was above the AT. This measurement, however, has not been widely used by researchers to detect the AT.

(c) Using Surface Electromyography

Moritani and deVries (80) demonstrated that the AT could be detected by using the technique of surface electromyography. They administered a graded exercise test on a bicycle ergometer to eighteen male and female subjects. At a particular exercise intensity they observed that the integrated electromyogram obtained from the lateral portion of the quadriceps muscle increased non-linearly (the point at which three consecutive values deviated above one standard error of estimate from the linear regression equation). They then administered the identical exercise test to the same subjects and determined their AT using the respiratory gas exchange criteria mentioned earlier. The correlations between the oxygen uptakes at the point of non-linear increase in the integrated electromyogram and that at the AT determined from the respiratory gas exchange criteria were 0.965, 0.893 and 0.973 for the male, female and pooled data respectively ($P<.001$ in each

case). The regression equation developed for predicting the absolute oxygen consumption at the AT was:

$$\text{IEMG AT (l/min)} = 0.990 \text{ GAS AT} - 0.054, \text{ SEE} = 0.15 \text{----- Eq. 3}$$

where IEMG AT = predicted oxygen consumption at the AT using surface EMG

GAS AT = oxygen consumption at AT determined from gas exchange measurements

SEE = standard error of estimate

<u>Factors Affecting the Accuracy of the Anaerobic Threshold</u>

During a graded exercise test, there are several factors that could affect the accuracy of the power output or oxygen consumption at the AT when it is detected by the respiratory gas exchange criteria described above. These are:

(1) Hyperventilation

Hyperventilation results in the release of excess carbon dioxide thereby decreasing the partial pressure of carbon dioxide in the alveoli. This excess release of carbon dioxide will also result in a transient increase in the respiratory exchange ratio thereby making it difficult to detect the true AT. If a breath by breath analysis of the respiratory measurements is done and no change is observed in the partial pressure of carbon dioxide in the alveoli, then it can be confirmed that the individual is not hyperventilating and the non-linear increases in the volume of carbon dioxide produced and the respiratory exchange ratio are due to the AT (82).

Wasserman and McIlroy (113) as well as Naimark et al. (82) studied the effect of voluntary hyperventilation during exercise on the

respiratory gas exchange ratio. They found that at low levels of exercise, deliberate hyperventilation increased the value of the respiratory exchange ratio significantly because the oxygen consumption was low. However, as the exercise intensity and oxygen uptake increased, the effect of deliberate hyperventilation on the respiratory exchange ratio decreased considerably. The average increase in its value due to deliberate hyperventilation at an oxygen uptake between 1 and 3 l/min was approximately between 0.02 and 0.01.

(2) Blood Temperature

An increase in blood temperature during exercise will result in excess carbon dioxide being ventilated without a change in the pressure of arterial or alveolar carbon dioxide because: (1) it increases the dissociation constant of carbonic acid and (2) it decreases the solubility of carbon dioxide (76, 82). However, if breath by breath measurements are taken, the effect of temperature on the carbon dioxide elimination and hence the respiratory exchange ratio is negligible because the temperature changes are slow and small and the decrease in plasma bicarbonate concentration per degree change in temperature is quite low (0.4 mEq/l/°C)(82).

(3) Oxymyoglobin Stores

The muscles store a limited amount of oxygen in the form of oxymyoglobin which can be utilized during exercise. This oxygen consumption is not reflected in the oxygen uptake measured at the lungs, but nevertheless, it does result in the production of carbon dioxide which acts as a stimulus for the ventilatory centre. However, its overall effect during exercise is minimal because the total amount of oxymyoglobin stored in man is quite low, about 200 ml. on the average (82).

(4) Substrate Concentration

Ivy et al. (56) studied the changes in the AT in a group of nine subjects when the blood glucose and free fatty acid levels were elevated. Compared to the control conditions, no change was observed in the oxygen consumption at the AT when the blood glucose levels were elevated, but when the blood borne free fatty acid levels were high, the oxygen consumption was significantly increased.

The affect of glycogen depletion on the AT is controversial. Wiswell et al. (133) observed a ten percent decrease in the oxygen consumption at the AT following a two hour exhaustive run in six fairly well trained marathon runners ($\dot{V}O_2$ max = 57.3 ml/kg/min) when the values were expressed either in litres/minute or as a percentage of the maximum oxygen uptake. In contrast, Hughes et al. (53) observed no significant differences in the work rate or oxygen consumption at the AT in nine male subjects as a result of glycogen depletion, despite significant decreases in the maximum work rate and maximum oxygen uptake.

(5) Mode of Exercise

As is the case for the maximum oxygen uptake (77), the mode of exercise seems to influence the value of the oxygen consumption at the AT. Davis et al. (24) observed significantly lower values for arm cranking compared to leg cycling or treadmill walk-running in thirty male student subjects. When these values were expressed as percentages of the respective maximum oxygen uptakes for the three modes of exercise, significantly lower values were once again observed for arm cranking compared to the other two modes of exercise which were not significantly different from each other. These investigators attributed

the lower values during arm cranking to: (1) the smaller muscle mass utilized during this mode of exercise compared to the other two modes (2) the lower training level of the arms compared to the legs (3) differences in motor unit recruitment patterns between the arms and the legs and (4) possible differences in the fibre type distribution between the arms and legs. Stamford et al. (104) observed significant differences in the absolute values of the oxygen consumption at the AT and the maximum oxygen uptake in ten males subjected to one and two legged cycling. However, when the former values were expressed as percentages of the latter, there were no significant differences between the two modes of exercise.

(6) Duration of Exercise at Each Intensity

The duration of exercise at each intensity during the graded test can affect the power output or oxygen consumption at the AT. Too short a duration at each intensity would lead to an overestimation of these values because of: (1) the utilization of stored phosphagens and oxymyoglobin in the muscles which transiently support the energy requirements for the first few seconds at each intensity (12) and (2) the delay in the diffusion of lactic acid from the muscle into the blood which would result in the lactate concentration measured at a particular intensity being due to conditions that existed at the previous intensity (104). Too long a duration at each intensity would unnecessarily prolong the duration of the test with the individual being subjected to undue stress (120). A review of the literature indicates that the testing protocol has not yet been standardized with the exercise duration at each intensity varying between one and four minutes (90, 120).

(7) Pedaling Speed

Hughes et al. (53) reported no significant differences in the oxygen consumption at the AT, expressed in litres/minute or as a percentage of the maximum oxygen uptake, when nine male subjects exercised at 50 rpm and 90 rpm on a bicycle ergometer. This was despite the fact that exercising at 90 rpm did result in a significant increase in the maximum oxygen uptake of the subjects.

Validity of the Anaerobic Threshold

The AT determined via respiratory gas exchange measurements has been validated against that determined by changes in blood variables on several occasions. Naimark et al. (82) calculated the excess carbon dioxide production in nineteen normal subjects and ten cardiac patients using the formula:

$$\text{Excess } \dot{V}CO_2 = \dot{V}CO_2 - R_{rest}(\dot{V}O_2) \text{ ------------------------------ Eq. 4}$$

When this excess carbon dioxide was plotted against the decrease in the plasma bicarbonate concentration of the arterial blood, a correlation coefficient of 0.98 was obtained. Davis et al. (24) as well as Hughes et al. (53), each using a group of nine male subjects, obtained correlation coefficients of 0.95 and 0.71 respectively, when they detected the oxygen consumption at the AT from venous blood lactate and respiratory gas exchange measurements. Likewise, Reinhard et al. (90), using a group of eleven male and four female subjects, observed that the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio was a minimum coincided with the power output at which there was an abrupt increase in the capillary blood lactate cincentration. The regression equation developed for predicting the oxygen consumption at the AT determined by the lactate

and $\dot{V}_E/\dot{V}O_2$ measurements was:

$$Y = 1.029X - 68.9; \; r = 0.9421 \quad \text{Eq. 5}$$

where Y = oxygen consumption at the highest work rate without a significant increase in lactate levels with regard to resting levels

X = oxygen consumption at the minimum $\dot{V}_E/\dot{V}O_2$ ratio

r = correlation coefficient between the oxygen consumption at the AT determined by lactate and $\dot{V}_E/\dot{V}O_2$ measurements

In contrast, Hughes et al. (53) reported that the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum did not correspond to the power output at the AT detected by a non-linear increase in the venous lactate or ventilation volume. The discrepancy between these results and those reported by Reinhard et al. (90) could be due to the fact that these investigators sampled blood from a forearm vein for the lactate measurements while Reinhard et al. (90) sampled capillary blood.

It is apparent from the above discussion that most of the evidence indicates a significant relationship between the AT detected from lactate and respiratory gas exchange measurements. However, Hagberg et al. (47) have questioned the theoretical basis of detecting the AT from respiratory gas exchange measurements in light of some evidence obtained on patients suffering from McArdle's disease. These individuals lack the enzyme phosphorylase and hence are unable to produce lactate because of their inability to metabolise energy via glycolysis. Despite this, these individuals demonstrate the non-linear increase in the ventilation volume (similar to that observed in normal subjects) when they are subjected to a graded exercise test. These researchers therefore felt that the non-linear increase in the ventilation volume observed at the AT was not due to the onset of metabolic acidosis but was only

coincidental, and that the large increases in the ventilation volume observed at intensities above the AT were probably due to neural afferents located within the exercising muscle. Their data on the normal subjects did show that the blood lactate concentration increased significantly at approximately seventy percent of the maximum oxygen uptake, while that at which the ventilation volume increased non-linearly occurred at seventy-three percent of the maximum oxygen uptake.

One of the major limitations of using blood lactate measurements to determine the validity of the AT is that the former is only an indirect measure of the lactate produced by the muscle (60). Even though lactate diffuses across the cell membrane quite rapidly, there is a time lag between its production in the muscle and its presence in the blood. Therefore, the 'true' AT could occur at a power output or oxygen consumption that is slightly lower than that reflected by blood lactate or respiratory gas exchange criteria.

Reliability of the Anaerobic Threshold

Several investigators have studied the test-retest and inter-tester reliability of detecting the AT from respiratory gas exchange measurements.

(1) Test-Retest Reliability

Rusko et al. (91) determined the oxygen consumption at the AT in twelve female physical education subjects on two separate occasions one week apart. The correlation coefficients obtained were 0.95, 0.88 and 0.80 when the values were expressed in l/min, ml/kg/min and percentage of the maximum oxygen uptake respectively. Davis et al. (22) examined the test-retest reliability of the AT prior to and following nine weeks of training. The correlation coefficients of the pooled (nine

experimental and seven control subjects) data prior to and following training were 0.94 and 0.95 respectively when the oxygen uptake values were expressed in l/min. When these values were expressed as a percentage of the maximum oxygen uptake, a correlation coefficient of 0.91 was observed on both occasions. In another investigation, Davis et al. (24) examined the test-retest reliability of the oxygen consumption at the AT in thirty male subjects for three different modes of exercise. The correlation coefficients obtained for arm cranking, leg cycling and treadmill walk-running were 0.77, 0.74 and 0.72 respectively. Although these correlation coefficients were significant, they were not very high. The researchers attributed the spurious estimates of the AT to: (1) the non-linear increase in oxygen consumption for some of the work increments which could have effected the value of the respiratory exchange ratio and (2) the possibility that a small quantity of lactate was produced when the exercise intensity was being increased, especially when the latter was close to the threshold value. Hughes et al. (53) reported reliability coefficients of 0.82 and 0.86 in nine male subjects for the oxygen consumption and power output at the AT determined by a non-linear increase in the ventilation volume. Naimark et al. (82) tested the reproducibility of the increase in the respiratory exchange ratio on the same day as well as after one week in four subjects. Although no correlation coefficients were reported, the results were highly reproducible. Wasserman et al. (120) tested the reproducibility of the oxygen consumption at the AT three times on the same day as well as one month and nine months apart for one subject who maintained his level of activity during this period. The values that they obtained were also highly reproducible.

(2) Inter-Tester Reliability

Rusko et al. (91) obtained a correlation coefficient of 0.92 when two different investigators were asked to determine the oxygen consumption at the AT from respiratory gas exchange measurements monitored during a graded exercise test on a bicycle ergometer. Weltman et al. (123) did not report a correlation coefficient for the inter-tester reliability of the power output at the AT for the thirty-three female subjects in their study. They did, however, make the statement that:

> "...in only one instance was there a discrepancy between investigators in choice of the appropriate work rate."[1]

Davis et al. (24) felt that the major limitation of detecting the AT from respiratory gas exchange measurements was the subjective nature of its determination. They state that:

> "...among ourselves, we routinely differ by 15-30 seconds in our estimates of AT times, although rarely do our estimates differ by more than 60 seconds."[2]

Their study showed that an error of thirty seconds in the choice of the AT time in one instance resulted in the oxygen consumption decreasing from sixty-five percent to fifty-eight percent of the individual's maximum oxygen uptake.

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[1]Weltman, A., Katch, V., Sady, S. and Freedson, P.; Onset of metabolic acidosis (anaerobic threshold) as a criterion measure of submaximum fitness; The Research Quarterly, Vol. 49: 218-227, 1978.

[2]Davis, J.A., Vodak, P., Wilmore, J.H., Vodak, J. and Kurtz, P.; Anaerobic threshold and maximal aerobic power for three modes of exercise; Journal of Applied Physiology, Vol. 41: 544-550, 1976.

Values of the Power Output and Oxygen Consumption at the Anaerobic Threshold Reported in the Literature

Table 1 summarizes the power output and oxygen consumption at the AT that have been reported in the literature. In several studies the data reported was insufficient, hence the blank spaces. The values for the absolute oxygen consumption at the AT ranged from a low of 0.8 l/min reported by Naimark et al. (82) to a high of 3.65 l/min reported by Wiswell et al (133). When the oxygen consumption at the AT is expressed as a percentage of the maximum oxygen uptake, the values ranged from a low of forty-six percent reported by Williams et al. (130) to a high of eighty-six percent reported by MacDougall (66). Skinner and McLellan (101) feel that these large variations could be due to the fact that the values at two different thresholds, both of which have been termed the AT, are being reported by the different investigators.

Physiological Factors Influencing the Anaerobic Threshold

(1) Age

Reinhard et al. (90) observed a significant negative correlation between the absolute value of the oxygen consumption at the AT and the age of sixty-six male and fifty female subjects ranging between twenty and sixty-five years. The regression equations and correlation coefficients obtained for the males and females were:

$Y = -0.0068X + 1296$; $r = -0.412$ for males ---------------- Eq. 6

$Y = -0.0051X + 1006$; $r = -0.427$ for females -------------- Eq. 7

where Y = predicted oxygen consumption (ml/min) at the AT

X = age in years

r = correlation coefficient between the age and oxygen

Table 1 - Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature

Investigators	Exercise mode	Subjects	Max. Oxygen Uptake 1/min	Max. Oxygen Uptake ml/kg/min	Anaerobic Threshold Oxygen Uptake 1/min	Anaerobic Threshold Oxygen Uptake ml/kg/min	Anaerobic Threshold %	Anaerobic Threshold Power Out KPM/min
Naimark et al. 1964 (V)	Bicycle ergometry and tread mill walking.	25 males			1.20			
		8 females			0.80			
Williams et al. 1967 (L)	Bicycle ergometry	13 males pre-training	2.89		1.32		46.0	
		post-training	3.06		1.88		62.0	
Williams et al. 1968 (L)	Bicycle ergometry	23 highly trained men	3.20				67.8	
Wesserman et al. 1973 (V)	Bicycle ergometry	85 male and female subjects			1.00			275 to 1200
Davis et al. 1976 (V)	Arm cranking	30 male	2.34	31.0	1.22		46.5	357.5
	Bicycle ergometry	subjects	3.68	48.8	2.61		63.8	1200
	Treadmill walk-running.		3.98	52.9	2.43		58.6	
MacDougall. 1977 (V)		10 non endurance athletes.		51.0			70.0	
		9 elite endurance runners		69.0			86.0	
Weltman et al. 1978 (V)	Bicycle ergometry	33 female students	2.26	36.2	1.11	18.1	50.0	513.4

Table 1 contd. - Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature

Investigators	Exercise mode	Subjects	Max. Oxygen Uptake		Anaerobic Threshold Oxygen Uptake			
			1/min	ml/kg/min	1/min	ml/kg/min	%	Power Out KPM/min
Stamford et al. 1978 (L)	Bicycle ergometry	10 male subjects						
	1 Legged		2.27		1.3		48.0	460
	2 Legged		3.5		1.7		48.0	920
Weltman and Katch. 1979 (V)	Bicycle ergometry	31 male subjects	3.74	51.36	2.23	30.58	59.5	972.7
Kindermann et al. 1979 (L)	Treadmill running	7 cross country skiers.	3.81	64.36		47.0	71.0	
Ivy et al. 1979 (L)	Bicycle ergometry	9 subjects					61.5	1330
Green et al. 1979 (V)	Bicycle ergometry	10 male students		53.9			75.8	
Davis et al. 1979 (V)	Bicycle ergometry	7 control males	2.83	35.2	1.23		44.6	
		9 experimental males						
		pre-training	2.77	31.10	1.36		49.4	
		post-training	3.47	40.00	1.96		57.00	
Reinhard et al. 1979 (V)	Bicycle ergometry	66 males and 50 females.						400

Table 1 contd. - Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature

Investigators	Exercise mode	Subjects	Max. Oxygen Uptake 1/min	Max. Oxygen Uptake ml/kg/min	Anaerobic Threshold Oxygen Uptake 1/min	Anaerobic Threshold Oxygen Uptake ml/kg/min	Anaerobic Threshold %	Power Out KPM/min
Wiswell et al. 1980 (V)	Bicycle ergometry	6 marathon runners	4.5	57.26	3.65		81.3	
Stephenson et al. 1980 (V)	Bicycle ergometry	6 females	2.33		1.59		68.7	
Rusko et al. 1980 (V)	Bicycle ergometry	15 female cross country skiers	2.69	47.3		40.9	85.7	
Ivy et al. 1980 (L)	Bicycle ergometry	13 males	3.54	50.6		27.8	54.2	
Sady et al. 1980 (V)	Bicycle ergometry	4 overweight females (control)						
		pre-training	2.31		1.28			
		post-training	2.22		1.14			
		7 overweight females (exptal.)						
		pre-training	2.23		1.02			
		post-training	2.82		1.62			
		7 overweight females (exptal.)						
		pre-training	2.09		0.97			
		post-training	2.63		1.23			

Table 1 contd. - Power Output and Oxygen Consumption at the Anaerobic Threshold reported in the Literature

Investigators	Exercise mode	Subjects	Max. Oxygen Uptake 1/min	Max. Oxygen Uptake ml/kg/min	Anaerobic Threshold Oxygen Uptake 1/min	Anaerobic Threshold Oxygen Uptake ml/kg/min	Anaerobic Threshold %	Anaerobic Threshold Power Out KPM/min
Hagberg et al. 1982 (L,V)	Bicycle ergometry	26 normal subjects (16 males, 10 females)	2.64	38.3			73 (V) 65-75 (L)	
Hughes et al. 1982 (L,V)	Bicycle ergometry	9 males						
		normal conditions	3.756		2.697 (L) 2.711 (V)		70.1 72.5	1267 1389
		glycogen depleted	3.721		3.118 (L) 2.639 (V)		81.1 71.6	1450 1256

L = AT determined from blood lactate measurements

V = AT determined from ventilatory measurements

consumption at the AT

The average value of the weight corrected power output at the AT in both sexes was approximately 1 watt/kg body weight for the twenty to thirty-nine years age group while that for the forty to sixty-five years age group was about twenty-five to thirty percent less. Rusko et al. (91) observed a significant positive correlation (r=0.54) between the oxygen consumption at the AT expressed as a percentage of a maximum oxygen uptake and the age of fifteen female cross country skiers whose ages ranged from fifteen to twenty years. This observation, however, is consistent with that reported by Reinhard et al. (90) because these investigators also reported a significant negative correlation (r=-0.63) between the maximum oxygen uptake and the age of the subjects. Wasserman et al. (120) did not report any specific trend with age when they studied the AT in eighty-five normal subjects. Their scattergram (Figure 7 in their article) however does show a tendency for the power output at the AT to decrease with age.

(2) Sex

Reinhard et al. (90) found that the absolute value of the power output or the oxygen consumption at the AT was approximately ten to thirty percent higher in males than in females. However, when the values were corrected for body weight, there were no significant differences between the sexes. From the scattergram given in Wasserman et al. (120), it was observed that the absolute work rate at which the AT occurred in females seemed lower than that in males. These investigators, however, did not report any specific differences between the sexes.

(3) Fibre Type

Human skeletal muscle fibres can be classified into two broad

categories (95, 124) namely: (1) type I fibres which have a slow contractile speed and a high oxidative, low glycolytic capacity and (2) type II fibres which have a fast contractile speed and a low oxidative, high glycolytic capacity. The type II fibres can be subdivided into type IIa and IIb fibres, the former having oxidative and glycolytic capacities that are intermediate to the type I and type IIb fibres respectively. If a relationship could be established between muscle fibre type and the oxygen uptake at the AT, then perhaps it would be possible to account for some of the inter-individual differences in the AT on the basis of fibre type composition. Theoretically, since the type I or slow twitch fibres are characterized by a high oxidative and low glycolytic capacity, one would expect a significant positive correlation between these fibres and the oxygen consumption at the AT. On the other hand, since the type IIb fibres are characterized by a low oxidative and high glycolytic capacity, a significant negative correlation would be expected between these fibres and the oxygen consumption at the AT.

The research that has been done to establish such a relationship is minimal and controversial. Using muscle biopsies from the vastus lateralis muscle of thirteen male subjects, Ivy et al. (57) observed significant correlations between the oxygen uptake at the AT expressed in ml/kg/min and as a percentage of the maximum oxygen uptake and: (1) the percentage of slow twitch fibres and (2) the cross sectional area of the slow twitch fibres expressed as a percentage of the total fibre area. The regression equations developed for (1) were:

(a) $Y = 0.31X + 37.9; \ r = 0.70$ -------------------------- Eq. 8

where Y = predicted oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake

X = percentage of slow twitch fibres

r = correlation coefficient between percentage of slow twitch fibres and oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake

(b) $Y = 0.31X + 11.72$; $r = 0.74$ ------------------------- Eq. 9

where Y = predicted oxygen consumption at the AT in ml/kg/min

X = percentage of slow twitch fibres

r = correlation coefficient between percentage of slow twitch fibres and oxygen consumption at the AT in ml/kg/min

No regression equations were developed for case (2), but the correlation coefficients reported were 0.62 and 0.73 for the two methods used to express the oxygen consumption at the AT.

Contrary to the above results, Green et al. (46) observed no significant correlations between the oxygen uptake at the AT expressed as a percentage of the maximum oxygen uptake and the percentage of type I, IIa or IIb fibres. The correlations ranged between -0.11 and 0.30. When the individual fibre type areas were expressed as a percentage of the total cross sectional area, the correlations were still insignificant and ranged between -0.44 and 0.37. Rusko et al. (91) observed no significant correlations between the percentage of slow twitch fibres in the vastus lateralis muscle and the oxygen uptake at the AT expressed in ml/kg/min or as a percentage of the maximum oxygen uptake. These investigators also failed to show a significant correlation between the percentage of slow twitch fibres and the maximum oxygen uptake, a finding which is contrary to other reports in the literature (57, 124).

(4) Enzyme Activities

Theoretically, an increase in the activity of the oxidative enzymes would have a tendency to delay the production of lactic acid and thereby increase the oxygen uptake at the AT. Therefore, it seems reasonable to hypothesize a significant positive correlation between the oxygen uptake at the AT and the oxidative enzyme activities. Experimental evidence to support this hypothesis is controversial. Ivy et al. (57) reported significant correlations between the respiratory capacity of the muscle measured as its capacity to oxidize pyruvate and: (1) the oxygen uptake at the AT expressed in ml/kg/min, $r = 0.94$ and (2) the oxygen uptake at the AT expressed as a percentage of the maximum oxygen uptake, $r = 0.83$. Rusko et al. (91) obtained significant correlations between the oxygen uptake at the AT expressed as a percentage of the maximum oxygen uptake and: (1) succinate dehydrogenase activity, $r = 0.63$ and (2) the sum of the standard scores (Z scores) of three oxidative enzymes, namely, succinate dehydrogenase, citrate synthetase and malate dehydrogenase, $r = 0.54$. Contrary to these results, Green et al. (46) did not observe a significant correlation between the oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake and the succinate dehydrogenase activity.

The M (muscle) form of the enzyme lactate dehydrogenase (LDH), predominant in type IIb skeletal muscle fibres, is responsible for the conversion of pyruvate to lactate in the final step of the glycolytic pathway (61). A high activity of this enzyme should, theoretically, result in a faster accumulation of lactic acid thereby resulting in a lower oxygen consumption at the AT or vice versa. Therefore, it seems reasonable to expect a significant negative correlation between the activity of this enzyme and the oxygen consumption at the AT.

Rusko et al. (91) did report a negative correlation between the total (M + H) activity of this enzyme and the oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake, but it wasn't significant.

(5) Menstrual Cycle

Stephenson et al. (105) examined the AT determined from respiratory gas exchange measurements in six adult females on five separate occassions during their menstrual cycles. Their results indicated no significant differences between measurements of the oxygen consumption at the AT and maximum oxygen uptake obtained on the different cycle days.

Effect of Physical Training on the Anaerobic Threshold

The effect of physical training on the AT can be studied in two ways: (1) indirectly by studying the relationship between the oxygen consumption at the AT and the maximum oxygen uptake and (2) directly by observing changes in the AT as a result of physical training.

(1) The Relationship between the Oxygen Consumption at the Anaerobic Threshold and the Maximum Oxygen Uptake

Trained individuals have higher maximum oxygen uptakes than untrained individuals because of their ability to transport, deliver and utilize oxygen more efficiently (3). Theoretically, these factors should also delay the onset of lactic acid production and thereby result in a higher oxygen consumption at the AT in the trained individuals. Therefore, it seems reasonable to hypothesize a significant positive correlation between the oxygen consumption at the AT and the maximum oxygen uptake. Several studies have examined this relationship and support this line of reasoning to some extent.

Davis et al. (22) obtained correlation coefficients of 0.75 and 0.72 prior to and following nine weeks of endurance training on a bicycle ergometer. The correlations reported were for the pooled data of the seven control and nine experimental male subjects who participated in their study. In another study, Davis et al. (24) reported correlation coefficients of 0.60, 0.52 and 0.70 during arm cranking, leg cycling and treadmill walk-running respectively in thirty male subjects. Weltman and Katch (121) as well as Weltman et al. (123) obtained correlation coefficients of 0.85 and 0.69 in thirty-one male and thirty-three female subjects respectively during bicycle ergometry. In the four studies cited above, the absolute values of the oxygen uptake (l/min) were utilized for the calculations. Weltman and Katch (121) observed a correlation of 0.72 between the oxygen consumption at the AT and the maximum oxygen uptake when the relative values (ml/kg/min) were used for the calculations. This was lower than the correlation of 0.85 obtained when the absolute oxygen uptake values were used, but nevertheless was still significant. Similarly, Ivy et al. (57) and Rusko et al. (91) reported significant correlation coefficients of 0.91 and 0.60 between the relative values of these two variables in thirteen male volunteers and fifteen female cross country skiers respectively during bicycle ergometry. The former researchers reported a significant correlation coefficient of 0.60 when the oxygen consumption at the AT was expressed as a percentage of the maximum oxygen uptake while the latter researchers reported this relationship to be insignificant. The regression equations developed by Ivy et al. (57) for predicting the oxygen consumption at the AT from the maximum oxygen uptake were:

(1) $Y = 0.84X - 14.89;\ r = 0.91$ ------------------------ Eq. 10

where Y = predicted oxygen consumption in ml/kg/min at the AT

X = maximum oxygen uptake in ml/kg/min

r = correlation coefficient between the oxygen consumption at the AT and the maximum oxygen uptake in ml/kg/min

(2) $Y = 0.61X + 23.4;\ r = 0.60$ ------------------------- Eq. 11

where Y = predicted oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake

X = maximum oxygen uptake

r = correlation coefficient between the oxygen uptake at the AT expressed as a percentage of the maximum oxygen uptake and the maximum oxygen uptake.

A summary of the correlation coefficients reported above is given in Table 2.

(2) Training Studies

Changes in the AT as a result of training have been studied by monitoring blood lactate (94, 98, 130) as well as respiratory gas exchange measurements (22, 92). Senay and Kok (98) observed a sixty-seven percent increase in the absolute oxygen consumption at the AT and an eleven percent increase in the absolute maximum oxygen uptake in five subjects who trained for approximately four hours/day for forty-three days at intensities ranging from forty to ninety percent of the maximum oxygen uptake. The values of the oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake also increased significantly from 39.6% before training to 59.5% after training. These researchers reported that the oxygen consumption at the AT continued to increase until the fifth week of training even though the maximum oxygen uptake stabilized after approximately the third week. Williams et al.

Table 2 - Correlation Coefficients between the Oxygen Consumption at the Anaerobic Threshold and the Maximum Oxygen Uptake reported in the Literature

			Correlations		
Investigators	Subjects	Exercise Mode	1/min	ml/kg/min	% of $\dot{V}O_2$ max
Davis et al. 1979	16 males	Bicycle ergometry			
		pre-training	0.75		
		post-training	0.72		
Davis et al. 1976	30 males	Arm cranking	0.60		
		Leg cycling	0.52		
		Treadmill walk-running.	0.70		
Weltman and Katch. 1978	31 males	Bicycle ergometry	0.85	0.72	
Weltman et al. 1978	33 females	Bicycle ergometry	0.69		
Rusko et al. 1980	15 females	Bicycle ergometry		0.60	Insignificant
Ivy et al. 1980	13 males	Bicycle ergometry		0.91	0.60
Hughes et al. 1982	9 males	Bicycle ergometry	0.86		

(130) reported a sixteen percent improvement in the oxygen consumption at the AT expressed as a percentage of the maximum oxygen uptake in thirteen male subjects who undertook:

> "a training program consisting of prolonged daily exercise (4 hours) at aerobic levels of work followed by exhaustive levels at maximal effort, lasting from 4 to 16 weeks."[3]

It should be noted that in both the studies cited above, the AT was detected from blood lactate measurements and no control group was included in the study.

Using respiratory gas exchange measurements, Davis et al. (22) studied the effects of nine weeks of endurance training on a bicycle ergometer on the changes in the oxygen consumption at the AT in nine middle aged men whose average maximum oxygen uptake was 31.1 ml/kg/min. After training at an average frequency of 4.1 sessions/week for approximately forty-five minutes/session at an intensity that required an oxygen consumption approximately fifty percent between the AT and maximum oxygen uptake, the subjects significantly increased their AT and maximum oxygen uptake by forty-four percent and twenty-five percent respectively. When the oxygen uptake at the AT was expressed as a percentage of the maximum oxygen uptake prior to and following training, a significant increase of fifteen percent was observed. Sady et al. (92), using the respiratory gas exchange technique, studied the effects

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[3] Williams, C.G., Wyndham, C.H., Kok, R. and Von Rahden, M.J.F.; Effect of training on maximum oxygen uptake and on anaerobic metabolism in man; <u>Internationale Zeitschrift for Angewandte Physiologie Einschliesslich Arbeits Physiologie,</u> Vol. 24: 18-23, 1967.

of two training intensities on the oxygen consumption at the AT in young female subjects. The high intensity group trained at an intensity that was above the AT (approximately eighty percent of the maximum oxygen uptake) while the low intensity group trained at an intensity that was below the AT (approximately forty percent of the maximum oxygen uptake). The subjects trained four times a week for a period of eight weeks with the total caloric expenditure per training session being equalized for the two groups. The results indicated that the high intensity group showed significant increases in the absolute oxygen consumption at the AT as well as the maximum oxygen uptake while the low intensity group showed a significant improvement only in the maximum oxygen uptake. Hence, these researchers concluded that in order to bring about significant changes in the AT, it was necessary to train at an intensity above the AT.

Significance of the Anaerobic Threshold

A high AT is of special significance to the endurance athlete because it enables him to work at a higher intensity for a longer duration at a lower oxygen cost. The reasons for this are outlined below.

(1) Ability to Perform at a Higher Exercise Intensity

It has been shown that endurance athletes are able to work for prolonged periods of time at exercise intensities that result in blood lactate concentrations just below those observed at their AT (16) and that these athletes do select such an exercise intensity for "optimal" endurance performance (35). The former is supported by Costill et al. (16) who observed an increase in the blood lactate concentration from a

resting level of 9.2 mg% to a value of approximately 16 mg% during a two hour running period on a treadmill at a speed of 15 kmh. This blood lactate concentration was very close to that observed at the AT of the subjects, approximately 17 mg%. The latter has been demonstrated by Farrell et al. (35) who showed that the treadmill velocity at which the plasma lactate concentration increased exponentially (these investigators preferred not to call it the anaerobic threshold) was more closely related to performance in races of different lengths (3.2 km to 42.2 km) than maximum oxygen uptake, percentage of slow twitch fibres, running economy and the oxygen consumption at the point at which the plasma lactate accumulation took place. Hence, if two individuals differed significantly in their AT's, then the one with the higher value would theoretically have a higher "optimal" work intensity than the one with the lower value and probably perform superiorly in an endurance event.

(2) Ability to Perform for Prolonged Periods

During prolonged exercise, fat is an important substrate for energy production (44). Since lactic acid inhibits the mobilization of fat from the adipose tissue (9, 41) it follows then that at exercise intensities above the AT, when the concentration of lactic acid is high, the amount of fat that will be available for energy production will be limited. In order to continue working at the same intensity, it would then be necessary to metabolize energy via carbohydrate sources, mainly muscle glycogen, the depletion of which has been associated with exhaustion during prolonged exercise (5,49). Therefore, an individual with a high AT will have decreased dependency on carbohydrate sources for energy

production and hence will be able to perform at a given exercise intensity for a longer duration than an individual with a low AT.

(3) Ability to Perform at a Lower Oxygen Cost

At exercise intensities above the AT, the ventilation volume increases non-linearly due to the additional stimulus to the respiratory centre as a result of increased carbon dioxide production (116), thereby increasing the $\dot{V}_E/\dot{V}O_2$ ratio. An increase in this ratio indicates that the oxygen cost of ventilation is increased, perhaps making less oxygen available to the muscles that are directly involved in the exercise. Hence, in order to continue working at the same intensity, it will be necessary to increase the oxygen consumption, thereby increasing the total energy cost of the exercise (66). Therefore, if two individuals were exercising at an intensity which was higher than the AT of one and lower than that of the other, then the mechanical efficiency in terms of energy cost would be greater in the latter subject.

Controversy Regarding the Use of the Term Anaerobic Threshold

The use of the term "Anaerobic Threshold" to denote the oxygen uptake or power output at which a significant amount of lactic acid accumulates in the blood has been questioned by some investigators (53, 64,101). This is because: (1) no direct evidence is available to substantiate the existence of muscle hypoxia at this exercise intensity, and therefore, Hughes et al. (53) preferred using the term "Ventilatory Threshold" when detecting this point non-invasively and (2) the production of lactic acid in the muscle cell is not necessarily the result of tissue hypoxia. Instead, it could be due to a "forced conversion" of pyruvic acid into lactic acid under predominantly aerobic conditions (101). If the rate of pyruvic acid (the immediate precursor

of lactic acid in glycolysis) production via aerobic glycolysis exceeds its rate of removal into the citric acid cycle (via acetyl CoA), then there will be some excess pyruvic acid available in the muscle cell. This pyruvic acid can be converted into lactic acid by the M form of the enzyme lactate dehydrogenase which has a high level of activity in the type II muscle fibres (61). Since the recruitment of these muscle fibres increases with the exercise intensity (31), the production of lactic acid in this manner seems quite feasible. Because of this distinct possibility, Skinner and McLellan (101) suggested that the term "Anaerobic Threshold" be replaced by "Aerobic Threshold". Wasserman (110), however, has recently refuted this fibre type theory and believes that the accumulation of large quantities of lactate during exercise occur in situations where the demand for oxygen is high and the supply low (i.e. hypoxic conditions), thereby justifying his use of the term "Anaerobic Threshold" and not any of the other terms suggested in the literature.

The Threshold of Decompensated Metabolic Acidosis

Reinhard et al. (90), who reported that the exercise intensity at which the concentration of lactic acid in the capillaries increased significantly coincided with the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum, provided evidence that a second threshold existed during a graded exercise test. These researchers demonstrated that the exercise intensity at which the pH in the capillaries decreased significantly seemed to coincide with the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum during the graded exercise test. This intensity, which they termed the Threshold of Decompensated Metabolic Acidosis (TDMA), occurred at approximately two-thirds the MEC compared to

the AT which they reported occurred at approximately one-third the MEC. The regression equation developed for predicting the oxygen consumption at the TDMA determined by the pH and $\dot{V}_E/\dot{V}CO_2$ measurements was:

$$Y = 0.8604X + 220.1; \ r = 0.8535 \text{ ---------------------Eq. 12}$$

where Y = oxygen consumption at the highest work rate without a significant decrease in pH values with regard to the resting value

X = oxygen consumption at the minimum $\dot{V}_E/\dot{V}CO_2$ ratio

r = correlation coefficient between the oxygen consumption at the TDMA determined by pH and $\dot{V}_E/\dot{V}CO_2$ measurements

Wasserman et al.(115) considered the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio began to increase to be the exercise intensity at which the respiration began to compensate for the increasing metabolic acidosis. These researchers reported that the increase observed in the $\dot{V}_E/\dot{V}CO_2$ ratio was due to a strengthened ventilatory stimulus (via the carotid bodies) as a result of the decreasing pH and was accompanied by a decrease in the partial pressure of carbon dioxide in the arterial blood ($PaCO_2$), which helped constrain the decrease in pH during the exercise test.

Kindermann et al. (64) as well as Skinner and McLellan (101) have outlined three phases of metabolism during a graded exercise test and on this basis suggested that two thresholds exist during such a test. According to the latter, the first phase, which recruited mainly the type I muscle fibres, was predominantly aerobic because there was no significant increase in the lactate concentration when compared to resting levels. The onset of phase II, which occurred between 40% and 60% of the maximum oxygen uptake, was characterized by a non-linear increase in the blood lactate concentration to a value of approximately

2 mmol/l and was primarily due to an imbalance between the rate of pyruvate production and its removal. This non-linear increase in lactate concentration was accompanied by the changes in the respiratory gas exchange parameters described earlier. This was the exercise intensity which they preferred to call the "Aerobic Threshold" instead of the "Anaerobic Threshold" as originally suggested by Wasserman and co-workers (110, 112, 113, 115, 116, 120). The period between phase II and III, termed the "Aerobic-Anaerobic Transition Period", recruited mainly the type I and IIa fibres and resulted in the blood lactate concentration rising to approximately 4 mmol/l. The onset of phase III, termed the "Anaerobic Threshold", was characterized by another non-linear increase in the blood lactate concentration along with all the associated changes in the gas exchange variables, with the exception of the F_ECO_2 which at this point began to decrease. This term was used because this final phase of exercise, which occurred between 65% and 90% of the maximum oxygen uptake, recruited all three fibre types: I, IIa and IIb and resulted in the production of lactic acid due to anaerobic metabolism. It is quite possible that the AT suggested by these researchers coincides with the TDMA observed by Reinhard et al. (90) during the graded exercise test.

The TDMA, like the AT, was also dependent upon age and sex. The regression equations computed by Reinhard et al. (90) for predicting the oxygen consumption at the TDMA from age for male and female subjects were:

$Y = -0.0144X + 2225$; $r = -0.459$ for males ---------- Eq. 13

$Y = -0.0089X + 1601$; $r = -0.363$ for females -------- Eq. 14

where Y = predicted oxygen consumption at the TDMA in ml/min

X = age in years

r = correlation coefficient between the age and the oxygen consumption at the TDMA

The negative correlations indicated that the oxygen consumption at the TDMA decreased with age in both sexes. The absolute values of the power output at the TDMA were ten to thirty percent less in the females, but when they were corrected for body weight no significant difference between the sexes was observed. For the twenty to thirty-nine year age group this value was 2 Watts/kg body weight with the values decreasing by twenty-five to thirty percent in the forty to sixty-five year age group.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Forty healthy, male subjects from the Royal Glenora Club in Edmonton volunteered to take part in this study. The subjects were informed of the testing and training procedures involved and thereafter offered their written consent for participation (Appendix A). The subjects came from a variety of backgrounds - lawyers, doctors, engineers, businessmen, tradesmen and students. A majority of the subjects were actively involved in sports such as tennis, badminton, squash, racquetball and handball. None of them were on the national team for any of these sports.

Anthropometric Data

The following anthropometric data was recorded for each subject: age in years, barefoot height in centimetres, mass in kilograms with the subject wearing swimming trunks and percent body fat.

The Beckman Metabolic Measurement Cart (MMC) (Beckman Instruments, Inc., Illinois, U.S.A.)

(1) Description

This system has been designed to facilitate rapid assessment of respiratory and metabolic parameters both at rest and during exercise. Briefly, the MMC consists of two major components: (1) a set of

analyzers or sensors for measuring the partial pressures of oxygen and carbon dioxide, volume and temperature of expired air, barometric pressure and time and (2) a programmable calculator which oversees the operation of the measurement cycles, performs all the required calculations and prints the calculated data as shown in Appendix B, pages 179 to 180. Further details regarding this system are available in Wilmore et al (131).

(2) Calibration

At the beginning of each testing session that this system was going to be used, it was calibrated for volume, partial pressures of oxygen and carbon dioxide, barometric pressure and temperature according to standards laid down in the manual supplied with the instrument. These calibrations were checked periodically throughout the testing session to ensure the accuracy of the measurements being taken.

Preliminary Testing

Approximately one week before the preliminary testing sessions, each subject was given written instructions (Appendix A) asking him to refrain from ingesting foods, nutrients and drugs and to avoid strenuous physical activity for at least two hours prior to the testing time. Each subject was administered preliminary tests designed to obtain the following information:

1) The values of the selected variables at the AT, TDMA and MEC.

2) Percent body fat.

(1) Determination of the AT, TDMA and MEC

(a) Preparation of the subject

The subject was fitted with a set of electrodes connected appropriately to a heart rate meter (Quinton Instrument Co., Model 650) so that the heart rate could be monitored throughout the exercise test. A mouth piece connected to the free end of the MMC was placed in the subject's mouth and a nose clip was fixed in a manner that would cause minimal discomfort to the subject. The seat height of the bicycle ergometer was adjusted for each subject so that when either foot that was on the pedal was at its lowest point, there was a slight bend in the knee joint. An illustration of the subject in the appropriate testing position is given in Figure 1.

(b) Test Protocol

The subject started pedalling the bicycle ergometer at sixty rpm with no resistance (0 KP) for a period of four minutes. The MMC, programmed to perform calculations every thirty seconds, was started after three minutes of free pedalling. Thereafter, the workload was increased by 0.5 KP (180 KPM/min) every minute until the subject reached his MEC. This was considered to be the exercise intensity at which the subject consumed the maximum amount of oxygen and/or was unable to continue exercising at the prescribed rate of sixty rpm. The 'shout' method of motivation was used as each subject approached his MEC.

(c) Detection of the AT and TDMA

Using the data from the MMC printouts, the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ ratios were calculated for each power output that the subject exercised at. Each of these ratios was then plotted separately against the power output and the intensity at which the $\dot{V}_E/\dot{V}O_2$

Figure 1 - Subject in the Appropriate Testing Position

ratio reached a minimum was considered to be the AT, while the intensity at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum was considered to be the TDMA. The power output, time, ventilation volume, absolute oxygen consumption, relative oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio at the AT, TDMA and MEC was recorded in this manner for each subject (see Appendix B).

To test whether the two thresholds suggested by Skinner and McLellan (101) coincided with the AT and TDMA, the F_EO_2 and F_ECO_2 values for each power output were plotted on the same graphs as the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ ratios respectively for each subject. A separate plot of the ventilation volume and carbon dioxide production against power output was also made for each subject.

(2) Determination of Percent Body Fat

Following the graded exercise test described above, the subject was allowed to rest for approximately half an hour. Thereafter, his percent body fat was determined by the underwater weighing technique described by Sloan (103) using the revised body density formula derived by Brozek et al (11). The calculations were performed as outlined in the data collection sheet, Appendix B.

Assignment of Subjects to the Treatment Groups

The forty subjects were initially ranked in descending order of their relative maximum oxygen uptakes. They were then blocked into two fitness categories - the top twenty subjects being classified as the high fit category and the bottom twenty subjects being classified as the low fit category. The subjects in each fitness category were then assigned to one of four treatment conditions by the technique of stratified randomization (36) so as to equalize the relative maximum

oxygen uptakes. This was done in the following manner. The twenty subjects in each fitness category were subdivided according to their rank order into five subgroups of four subjects each. From each of these subgroups, individuals were randomly assigned to one of the following four treatment groups:

1) Control Group, CG
2) Threshold Group, TG
3) Above Threshold Group, ATG
4) Interval Training Group, ITG

This procedure resulted in the formation of four treatment groups of five subjects each in the high and low fit categories. After this initial assignment of the subjects to the groups, a one-way analysis of variance (132) was used for each category to determine whether there were any significant differences between the treatment groups in that category for their relative maximum oxygen uptakes. If there was a significant difference in either of the fitness categories, the process of randomly reassigning the subjects to the treatment groups in that category was repeated until the analysis of variance revealed no significant differences between them. Once these groups were finalized, each subject was ranked in descending order (1 through 5) of his relative maximum oxygen uptake in that group.

The Training Program

The training program was of eight weeks duration with each subject in the experimental groups training three times a week with a minimum of twenty-four hours rest between training sessions. The training intensity of each group was regulated in the following manner.

CG - the subjects in this group did not undergo any training but were asked to maintain their normal activity patterns throughout the duration of the study.

TG - each subject in this group trained at a power output (KPM/min) requiring an oxygen uptake that was approximately ten percent above that at his AT.

ATG - each subject in this group trained at a power output (KPM/min) requiring an oxygen uptake that was approximately fifty percent between that at this AT and MEC.

ITG - each subject in this group trained intermittently at a power output (KPM/min) requiring approximately one hundred percent of his maximum oxygen uptake. The work:rest intervals were one minute each.

The training power output for each subject was determined from the graph that was previously drawn to detect the AT and TDMA from the respiratory gas exchange measurements. The pedalling frequency in all cases was sixty rpm. The subject attempted to maintain this pedalling speed with the aid of audio-visual feedback from a metronome (Franz, Model LM-FB-4). Heart rate was monitored continuously during each training session and was used to maintain the prescribed training intensity of the subject.

The three experimental groups in each fitness category were equated for the total amount of work done per training session in the following manner. Each subject in the TG trained for thirty minutes every session. The total work done by each subject in this group, i.e. power output in KPM/min x 30, was then calculated. This value was then divided by the power output (KPM/min) that the subjects of the same rank order in the ATG and ITG were supposed to train at, so that the total

time for each of their training sessions could be determined. A sample calculation for subjects of the rank order 1 in the three experimental groups of the low fit category is given in Table 3. Similar calculations were done for all the other subjects in the three experimental groups. If a subject was unable to complete the prescribed amount of work in one attempt, he was given a sufficient amount of rest so that he could resume training and complete the balance of the work to be done for that session.

Mid and Post Training Testing

After twelve training sessions, each subject was again administered the bicycle ergometer test to determine his AT, TDMA and MEC. The training power output for the remaining twelve sessions was then revised on on the basis of any changes in the AT and/or MEC that resulted from the previous twelve training sessions. After twenty-four training sessions, each subject was readministered the bicycle ergometer test to determine his AT, TDMA and MEC. Prior to the mid and post training tests, the subjects were advised to follow the instructions given in Appendix A so that their diet and exercise patterns immediately prior to testing were controlled. The pre, mid and post training testing was completed over a span of approximately ten weeks.

Experimental Design

The experimental design of this study corresponded to a three factor design in which Factor A had two levels, namely the high and low fit categories, Factor B had four levels, namely the four treatment conditions (CG, TG, ATG and ITG) and Factor C had three levels, namely

<u>Table 3 - Method of Equating the Total Amount of Work Done Per Training Session</u>

Fitness Category	Subject/Rank Order	Training Power Output KPM/min	Exercise Time mins:secs	Total Work Done KPM
	TG1	810	30:00	24300
Low	ATG1	1260	$\frac{24300}{1260}$ = 19:20	1260 x 19:20 = 24300
	ITG1	1800	$\frac{24300}{1800}$ = 13:30	1800 x 13:30 = 24300

Note: Calculations were performed for all the other subjects of similar rank order in the high and low fit categories.

the pre, mid and post training values of the selected variables at the AT, TDMA and MEC.

Statistical Analysis

The anthropometric data and the pre training absolute as well as relative oxygen uptake at the AT and MEC (i.e. maximum oxygen uptake) of the high and low fit categories was subjected to a one-way analysis of variance (36) to determine significant differences between the two fitness categories.

The data collected for each of the variables at the AT, TDMA and MEC on the pre, mid and post tests was subjected to the following statistical treatments:

1) Determination of the Pearson product-moment correlations for the high fit, low fit and combined high and low fit categories. The data of the CG was excluded when computing the correlations for the mid and post training tests.
2) A three-way analysis of variance with repeated measures on the last factor (63, 132) followed by the Greenhouse-Geisser conservative test (132) to determine the significant 'F' ratios. A post hoc Scheffe Test (132) was used to locate the differences between test measurements, treatment conditions and fitness categories.

For all the above computations, the .05 level of significance was selected.

CHAPTER IV

RESULTS

This chapter is divided into four sections. In Section A, the characteristics of the subjects and the assignment of the subjects to the treatment groups are presented. In Section B, the pre training curves for the $\dot{V}_E/\dot{V}O_2$ ratio, $\dot{V}_E/\dot{V}CO_2$ ratio, F_EO_2, F_ECO_2, ventilation volume and carbon dioxide production during the graded exercise test are described. In Section C, the inter-correlations between the AT, TDMA and MEC are reported for the selected variables on the three test trials. In Section D, the effect of the four treatments on the selected variables at the AT, TDMA and MEC are reported.

SECTION A

Characteristics of the Subjects

The characteristics of the forty subjects who completed the initial testing are given in Table 4. The subjects are ranked in order of their relative maximum oxygen uptakes. The absolute and relative values of the oxygen uptake at the AT along with the age, height, weight and percent body fat of these subjects is also included in this table. No significant difference was observed between the two fitness categories for the height and body weight of the subjects. The age and percent body fat of the high fit category was significantly lower than that of the low fit category. The absolute and relative oxygen consumptions at

Table 4 - Characteristics of High Fit Subjects

Subject Rank	Age yrs	Height cms	Weight kgs	Percent Fat	$\dot{V}O_2$ max 1/min	$\dot{V}O_2$ max ml/kg/min	AT 1/min	AT ml/kg/min
1	27	177.8	66.1	12.2	3.81	57.6	1.98	30.0
2	36	185.4	83.4	19.1	4.30	51.6	1.97	23.6
3	20	182.9	79.4	14.5	3.95	49.7	1.50	18.9
4	21	182.9	77.7	11.8	3.84	49.7	1.49	19.2
5	18	174.0	60.3	10.6	2.99	49.6	1.53	25.4
6	21	174.0	68.1	6.0	3.38	49.6	1.42	20.9
7	26	176.0	65.0	9.8	3.09	47.4	1.41	21.6
8	34	193.0	87.6	20.3	4.02	47.4	1.62	19.2
9	35	172.7	70.7	12.9	3.34	47.3	1.57	22.0
10	21	172.7	65.8	11.3	3.10	45.7	1.41	21.5
11	22	180.0	86.7	20.1	3.88	44.8	2.29	26.4
12	33	182.9	73.4	7.0	3.34	44.5	1.42	19.3
13	23	180.0	82.3	8.3	3.72	44.5	1.35	16.5
14	18	188.0	71.0	18.1	3.14	44.2	1.83	25.8
15	36	180.3	87.2	13.8	3.76	43.1	1.44	16.5
16	30	167.2	59.5	16.5	2.53	42.6	1.07	18.0
17	20	185.4	65.4	6.1	2.80	42.6	1.03	15.8
18	36	180.3	81.6	18.2	3.48	42.5	1.68	20.5
19	32	180.3	75.9	17.1	3.20	42.1	1.49	19.6
20	33	182.9	83.1	18.8	3.50	42.1	1.63	19.6
Mean ± S.D.	27.1* ± 6.8	179.9 ± 6.0	74.5 ± 9.2	13.6* ± 4.7	3.46 ± 0.46	46.4* ± 4.3	1.56 ± 0.29	21.0* ± 3.8

* = values significantly different from those of low fit subjects at the .05 level.

Table 4 contd. - Characteristics of Low Fit Subjects

Subject Rank	Age yrs	Height cms	Weight kgs	Percent Fat	$\dot{V}O_2$ max 1/min	ml/kg/min	AT l/min	ml/kg/min
21	33	193.0	95.4	25.0	4.01	42.0	1.51	15.8
22	42	179.1	78.6	17.1	3.26	41.5	1.50	19.1
23	38	175.3	63.8	21.7	2.54	39.8	0.96	15.1
24	28	180.3	66.5	12.2	2.65	39.8	1.26	19.0
25	30	177.2	82.0	11.2	3.25	39.6	1.61	19.6
26	33	175.2	75.3	15.4	2.94	39.1	1.24	16.4
27	27	180.3	71.0	12.4	2.77	39.0	1.06	14.9
28	42	177.8	81.0	27.8	2.97	36.7	1.25	15.4
29	38	181.6	80.2	10.8	2.93	36.6	1.09	13.6
30	27	175.3	75.0	10.7	2.72	36.2	1.47	19.6
31	32	182.2	83.7	20.1	2.98	35.6	1.45	17.3
32	33	176.5	71.3	16.5	2.49	35.0	1.29	18.0
33	37	180.3	87.5	22.1	3.04	34.7	1.45	16.6
34	38	168.9	74.0	25.4	2.50	33.8	0.74	10.0
35	32	185.4	88.9	19.8	3.00	33.7	1.03	11.6
36	35	172.7	90.1	29.7	2.75	32.8	1.30	14.4
37	29	182.9	78.6	21.1	2.58	32.8	1.13	14.4
38	34	167.6	70.3	27.2	2.21	32.7	1.18	16.7
39	38	185.4	75.9	29.5	2.48	32.6	1.50	19.7
40	41	179.1	96.6	24.6	2.82	29.2	1.28	13.3
Mean ± S.D.	34.4* ± 4.8	178.8 ± 5.8	79.3 ± 9.1	20.0* ± 6.4	2.84 ± 0.36	36.2* ± 3.7	1.26 ± 0.19	16.0* ± 2.8

* = values significantly different from those of high fit subjects at the .05 level.

the AT and MEC (i.e. the maximum oxygen uptake) were significantly higher in the high fit category than in the low fit category.

Assignment of the Subjects to the Treatment Groups

The assignment of the forty subjects to the four treatment groups in each fitness category by the stratified randomization technique is given in Table 5. Although these treatment groups were initially equated on the basis of the relative maximum oxygen uptake, the statistical analysis also revealed no significant differences between them for the following variables: (1) absolute maximum oxygen uptake (2) absolute and relative oxygen uptake at the AT and (3) power output at the AT. The 'F' values and the probability levels of the above analyses of variance are given in Table 6. The summaries of the analyses of variance are given in Tables 77 to 86, Appendix D.

Attrition Rate

Of the forty subjects who completed the initial test and commenced training, thirty-eight subjects completed the study in its entirety. Two subjects were forced to drop out of the study - one due to injury and the other due to relocation. The two subjects who dropped out - ranks 2 from the ATG in the high fit category and TG in the low fit category, are marked with asterisks in Table 5. This resulted in an unequal number of subjects in the treatment groups in both and high and low fit categories. The total number of subjects in the two fitness categories was the same - i.e. nineteen subjects each.

Table 5 - Assignment of Subjects to the Treatment Groups by the Technique of Stratified Randomization (High Fit Category)

Overall Rank	Group/ Rank	Max. Oxygen Uptake 1/min	ml/kg/min	Anaerobic Threshold 1/min	ml/kg/min	KPM/min
2	CG1	4.30	51.6	1.97	23.6	900
5	CG2	2.99	49.6	1.53	25.4	900
9	CG3	3.34	47.3	1.57	22.0	900
13	CG4	3.72	45.2	1.35	16.5	540
17	CG5	2.80	42.7	1.03	15.8	540
Mean $\pm$ SD		3.43$\pm$ 0.60	47.1$\pm$ 3.7	1.49$\pm$ 0.34	20.6$\pm$ 4.3	756$\pm$ 197
3	TG1	3.95	49.7	1.50	18.9	540
7	TG2	3.09	47.4	1.41	21.6	720
10	TG3	3.10	45.7	1.41	21.5	720
16	TG4	2.53	42.6	1.07	18.0	540
20	TG5	3.50	42.1	1.63	19.6	720
Mean $\pm$ SD		3.23$\pm$ 0.53	45.5$\pm$ 3.2	1.41$\pm$ 0.21	19.9$\pm$ 1.6	648$\pm$ 99
4	ATG1	3.84	49.4	1.49	19.2	720
8	ATG2*	4.02	47.4	1.63	19.8	720
12	ATG3	3.34	45.5	1.42	19.3	720
14	ATG4	3.14	44.2	1.83	25.8	900
18	ATG5	3.48	42.5	1.68	20.5	900
Mean $\pm$ SD		3.56$\pm$ 0.36	45.7$\pm$ 2.9	1.61$\pm$ 0.16	20.9$\pm$ 2.8	792$\pm$ 99
1	ITG1	3.81	57.6	1.98	30.0	900
6	ITG2	3.38	49.6	1.42	20.9	900
11	ITG3	3.88	44.8	2.29	26.4	1080
15	ITG4	3.76	43.1	1.44	16.5	720
19	ITG5	3.20	42.1	1.49	19.6	720
Mean $\pm$ SD		3.60$\pm$ 0.30	47.4+ 6.4	1.73$\pm$ 0.39	22.7$\pm$ 5.4	864$\pm$ 151

* Subject did not complete the study

Table 5 contd. - Assignment of Subjects to the Treatment Groups by the Technique of Stratified Randomization (Low Fit Category)

Overall Rank	Group/ Rank	Max. Oxygen Uptake 1/min	Max. Oxygen Uptake ml/kg/min	Anaerobic Threshold 1/min	Anaerobic Threshold ml/kg/min	Anaerobic Threshold KPM/min
23	CG1	2.54	39.8	0.96	15.1	540
27	CG2	2.77	39.0	1.06	14.9	540
29	CG3	2.93	36.6	1.09	13.6	540
33	CG4	3.04	34.7	1.45	16.6	720
38	CG5	2.21	32.7	1.18	16.7	720
Mean ± SD		2.70± 0.33	36.5± 3.0	1.15± 0.19	15.4± 1.3	612± 99
22	TG1	3.26	41.5	1.50	19.1	720
26	TG2*	2.94	39.1	1.24	16.4	540
31	TG3	2.98	35.6	1.45	17.3	720
36	TG4	2.75	32.7	1.30	14.4	720
40	TG5	2.82	29.2	1.28	13.3	540
Mean ± SD		2.95± 0.20	35.6± 4.9	1.35± 0.12	16.1± 2.3	648± 99
24	ATG1	2.65	39.8	1.26	19.0	720
28	ATG2	2.97	36.7	1.25	15.4	540
32	ATG3	2.49	35.0	1.29	18.0	720
34	ATG4	2.50	33.8	0.74	10.0	360
37	ATG5	2.58	32.8	1.13	14.4	540
Mean ± SD		2.64± 0.20	35.6± 2.8	1.13± 0.23	15.4± 3.5	576± 150
21	ITG1	4.01	42.0	1.51	15.8	720
25	ITG2	3.25	39.6	1.61	19.6	720
30	ITG3	2.72	36.2	1.41	19.6	720
35	ITG4	3.00	33.7	1.03	11.6	360
39	ITG5	2.48	32.6	1.50	19.7	900
Mean ± SD		3.09± 0.59	36.8± 4.0	1.42± 0.22	17.3± 3.6	684± 198

* Subject did not complete the study

Table 6 - Pre Training Comparisons between Treatment Groups of Selected Variables at the Anaerobic Threshold and Maximum Exercise Capacity in the High and Low Fit Categories

Category	Variable	'F' Ratio	Probability
High	$\dot{V}O_2$ max, ml/min	0.65	0.594
	$\dot{V}O_2$ max, ml/kg/min	0.27	0.844
	$\dot{V}O_2$ at AT, ml/min	1.15	0.361
	$\dot{V}O_2$ at AT, ml/kg/min	0.47	0.708
	Power output at AT, KPM/min	2.00	0.155
Low	$\dot{V}O_2$ max, ml/min	1.68	0.211
	$\dot{V}O_2$ max, ml/kg/min	0.14	0.935
	$\dot{V}O_2$ at AT, ml/min	2.80	0.073
	$\dot{V}O_2$ at AT, ml/kg/min	0.49	0.691
	Power output at AT, KPM/min	0.53	0.666

Note: The Summaries of the Analyses of Variance are given in Tables 77 to 86, Appendix D.

SECTION B

The $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio, F_EO_2, F_ECO_2, Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test.

The path followed by the $\dot{V}_E/\dot{V}O_2$ curve during the graded exercise test was as reported by Reinhard et al. (90). Generally speaking, the $\dot{V}_E/\dot{V}O_2$ ratio was relatively high at the start of the graded exercise test. Thereafter, as the power output increased the $\dot{V}_E/\dot{V}O_2$ ratio decreased up to a point when it reached a minimum value. Further increases in the power output resulted, in most cases, in a continuous increase in the $\dot{V}_E/\dot{V}O_2$ ratio until the MEC was reached. The $\dot{V}_E/\dot{V}O_2$ ratio at the MEC was usually close to or higher than the value at the start of the test. A typical trace of the $\dot{V}_E/\dot{V}O_2$ curve against the power output for one subject (Rank 4 in the ATG, low fit category) is illustrated in Figure 2. The same curve is illustrated in Figure 3 for the sample of thirty-eight subjects who completed the study. The values of the $\dot{V}_E/\dot{V}O_2$ ratio are calculated by pooling the pre training values of the ventilation volume and oxygen consumption for all thirty-eight subjects at each power output.

The gross shape of the $\dot{V}_E/\dot{V}CO_2$ curve, in agreement with Reinhard et al. (90), was similar to that described for the $\dot{V}_E/\dot{V}O_2$ curve - i.e. the $\dot{V}_E/\dot{V}CO_2$ ratio decreased with increasing power output up to a point where it reached a minimum value and subsequently increased until the MEC was reached. The ratio at the MEC was usually close to or lower than the value at the start of the test. The power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum was always greater than that at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum. A sample trace of the $\dot{V}_E/\dot{V}CO_2$ curve

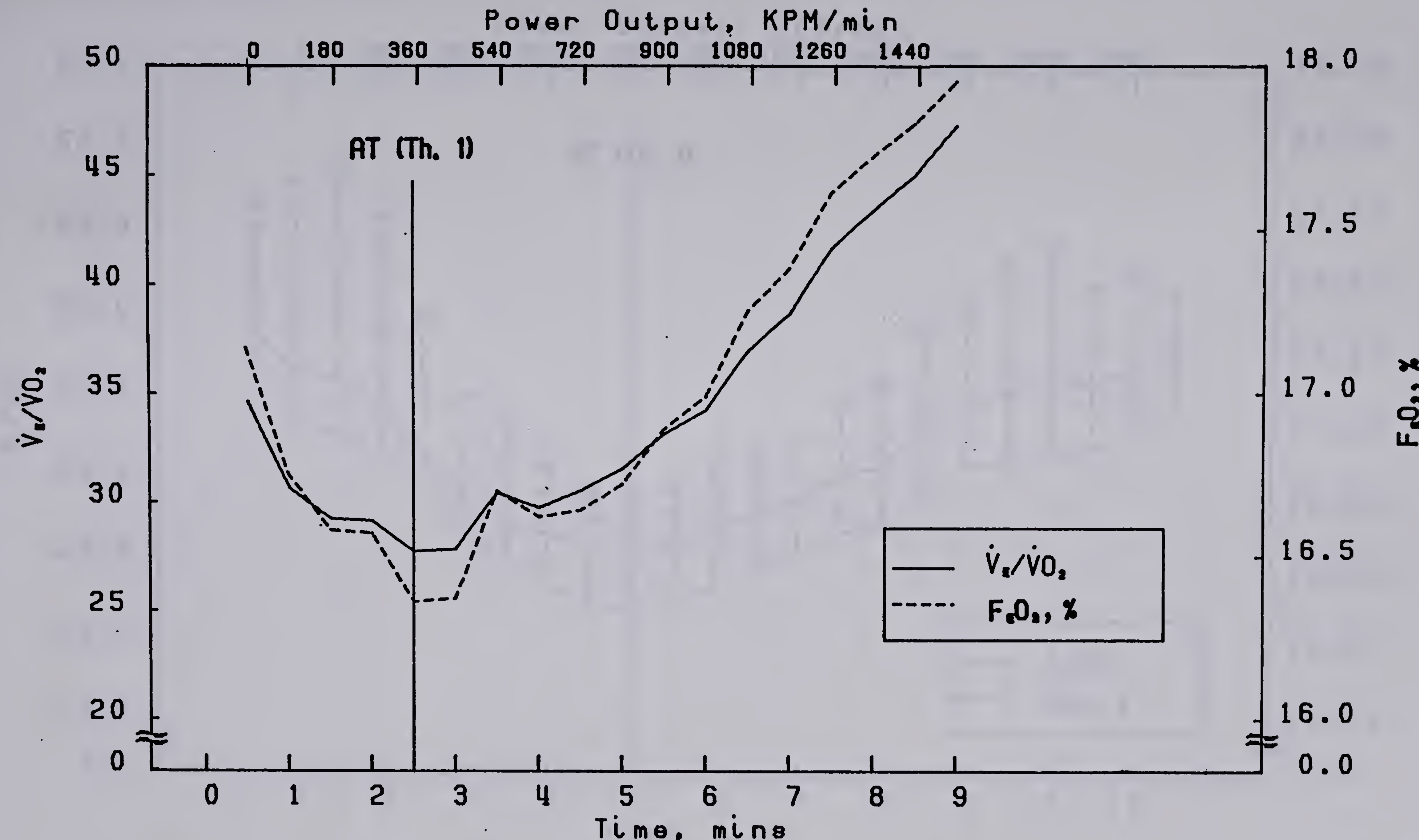


Figure 2 - The Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for One Subject.

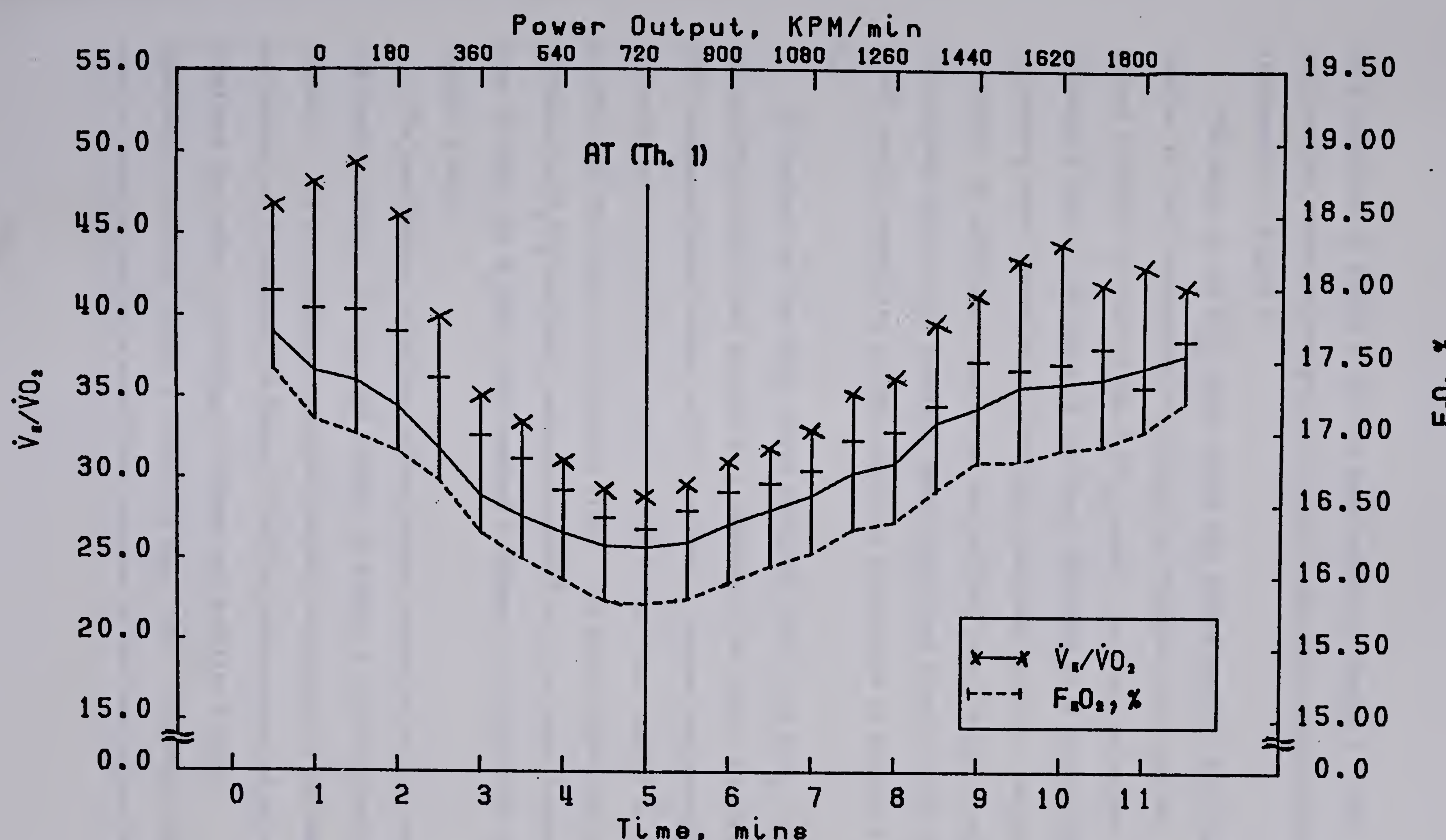


Figure 3 - The Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for the Sample of Thirty Eight Subjects

is illustrated in Figure 4 for the same subject in Figure 2. The pre training curve for the pooled values of the thirty-eight subjects is illustrated in Figure 5.

The shape of the F_EO_2 curve during the graded exercise test was similar to that hypothesized by Skinner and McLellan (101) and was almost identical to that of the $\dot{V}_E/\dot{V}O_2$ curve - i.e., the value was relatively high at the start of the test, decreased to a minimum with increasing power output and subsequently increased until the MEC was attained. Of particular importance was the fact that the F_EO_2 reached its minimum value at the identical power output and time at which the $\dot{V}_E/\dot{V}O_2$ ratio reached its minimum value, as illustrated in Figures 2 and 3.

In contrast to the three curves discussed above, the F_ECO_2 during the graded exercise test started at a relatively low value, increased with increasing power output until it reached a maximum and subsequently decreased until the MEC was reached. This pattern was similar to that hypothesized by Skinner and McLellan (101). The power output and time at which the F_ECO_2 reached a maximum coincided with the power output and time at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum, as illustrated in Figures 4 and 5.

The ventilation volume and carbon dioxide production curves during the graded exercise test for the subject in Figure 2 are illustrated in Figure 6. The pre training means and standard deviations of the same two curves are illustrated in Figure 7 for the thirty-eight subjects who completed the study. According to Skinner and McLellan's (101) hypothesis, the power output at which the F_EO_2 began to increase would also be characterized by a non-linear increase in the ventilation volume

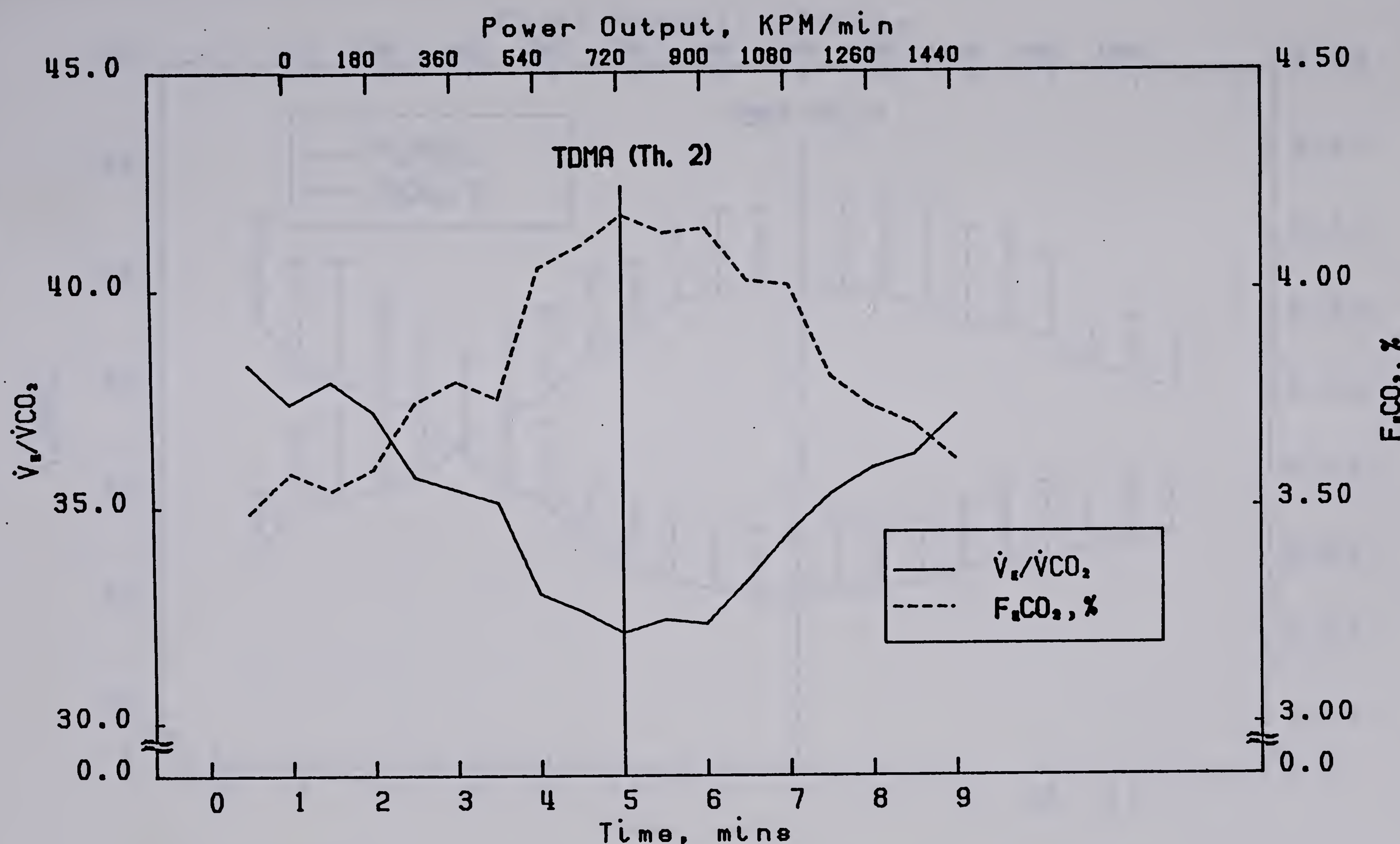


Figure 4 - The Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for One Subject

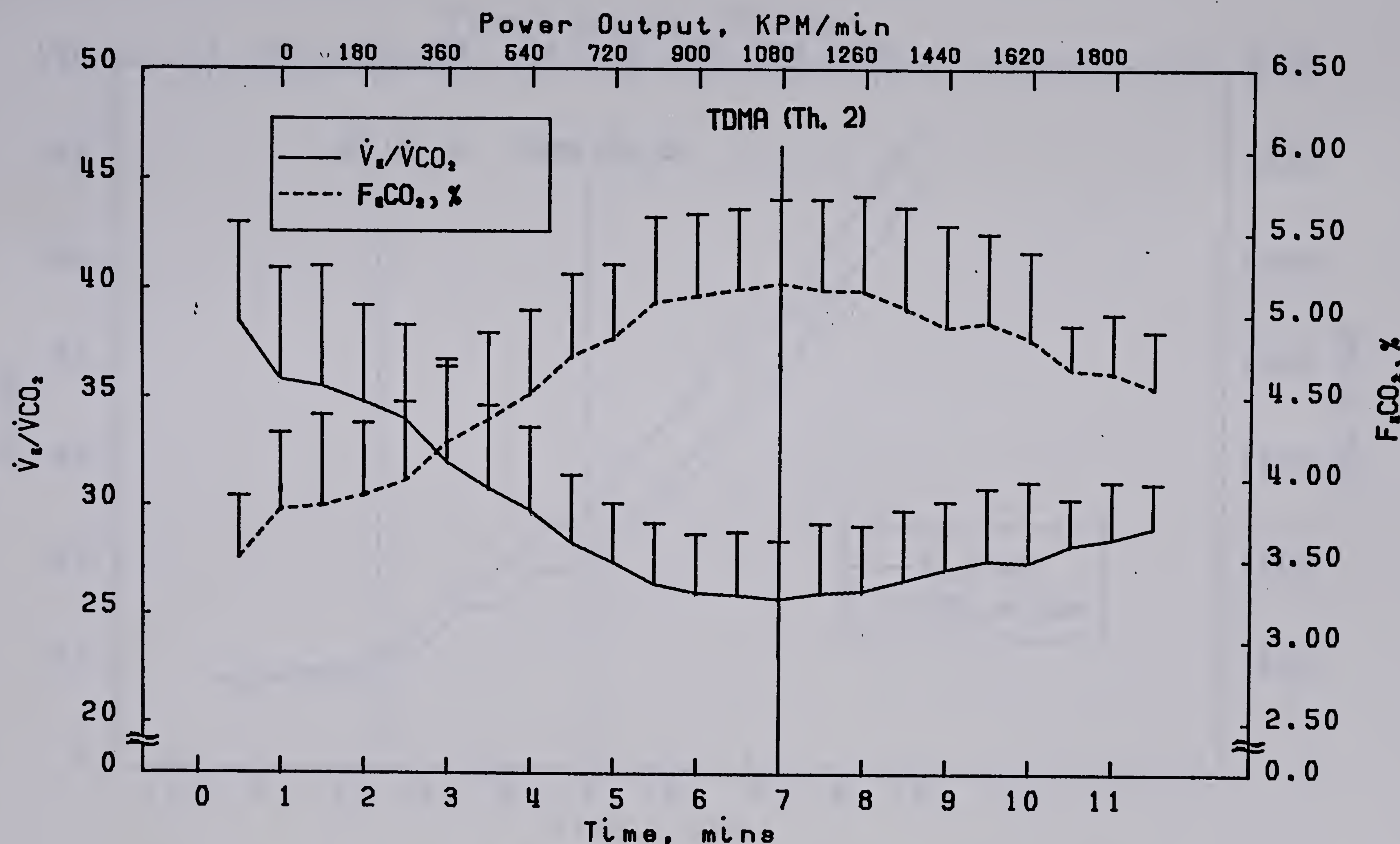


Figure 5 - The Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for the Sample of Thirty Eight Subjects

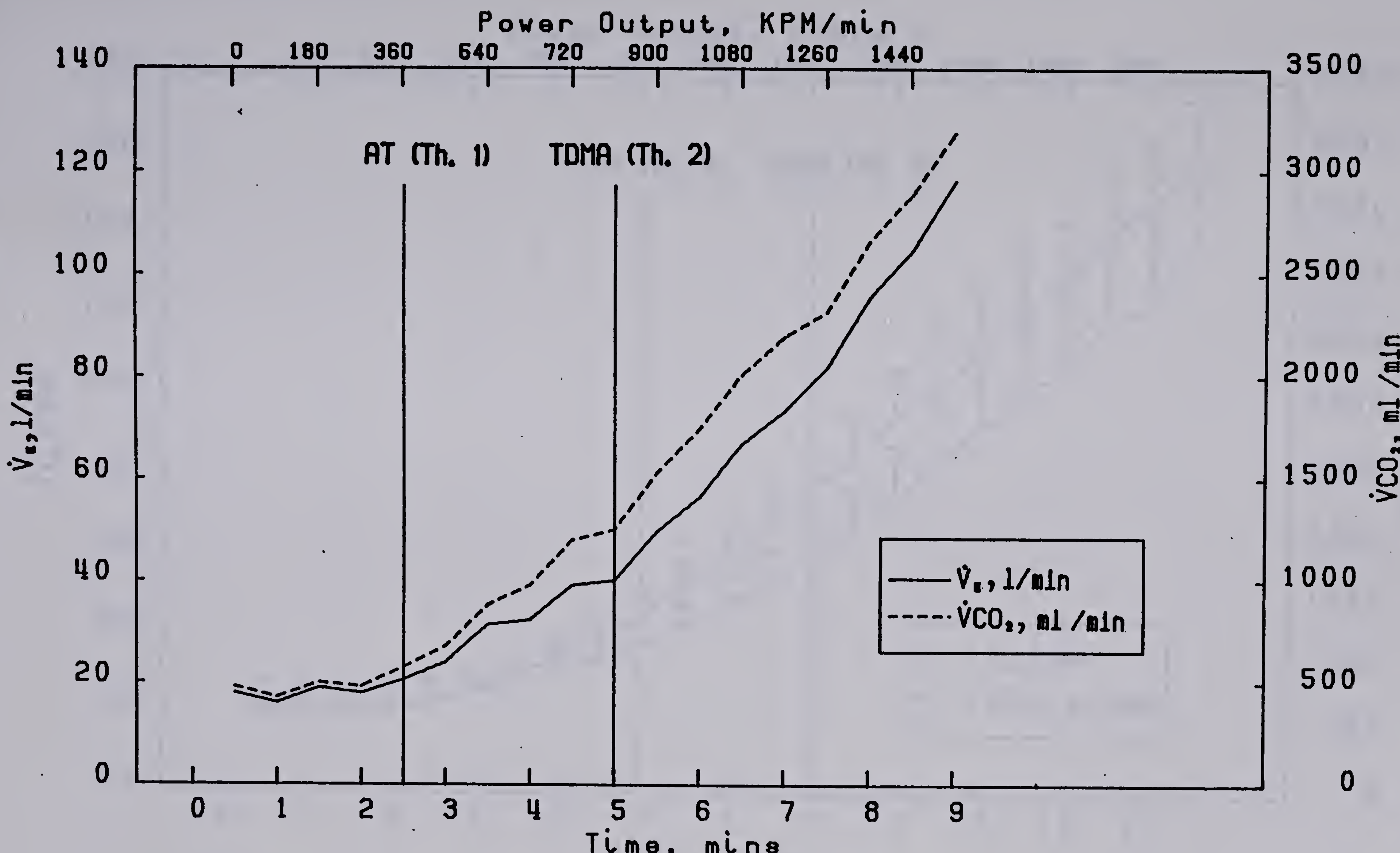


Figure 6 - The Pre Training Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test for One Subject

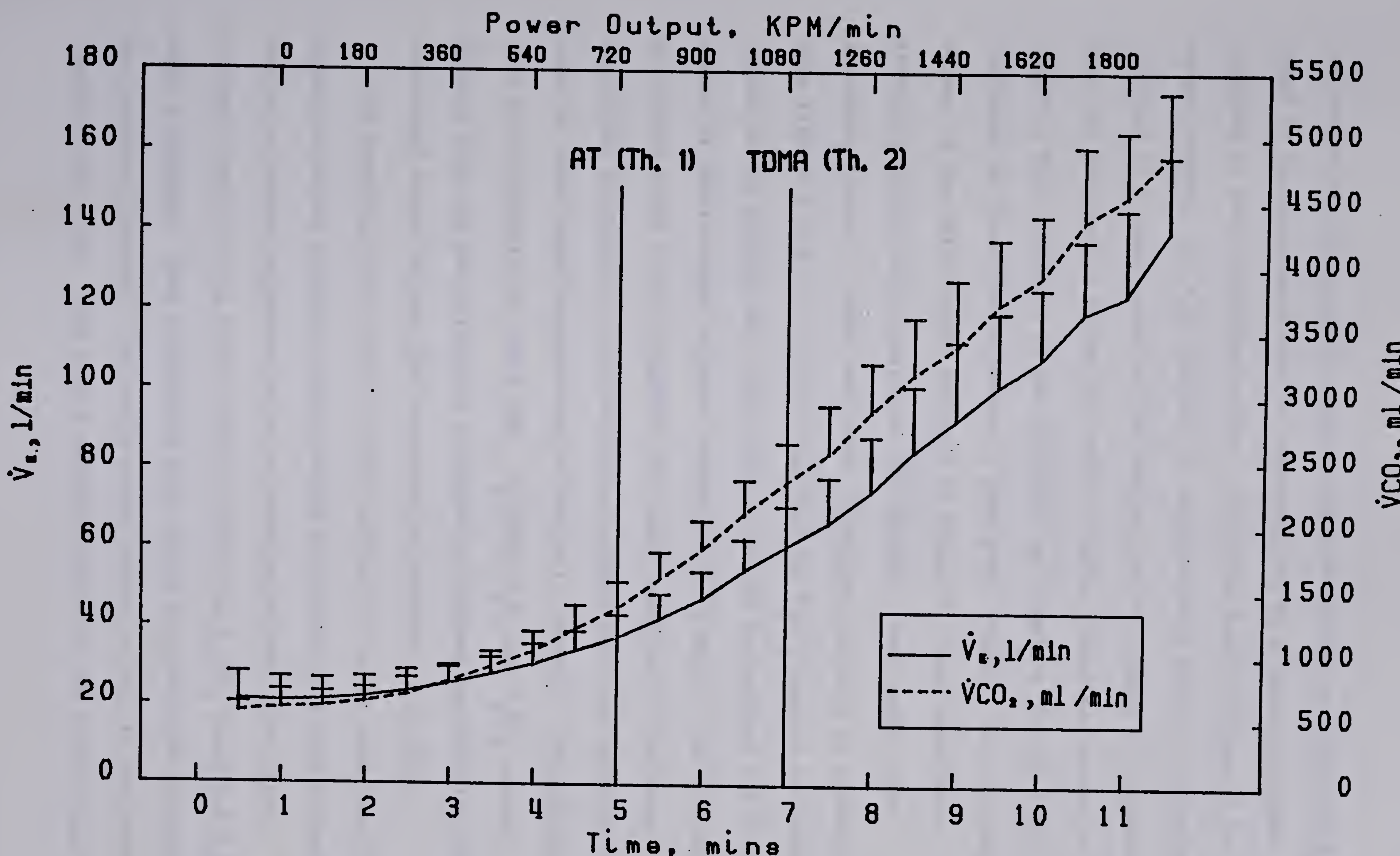
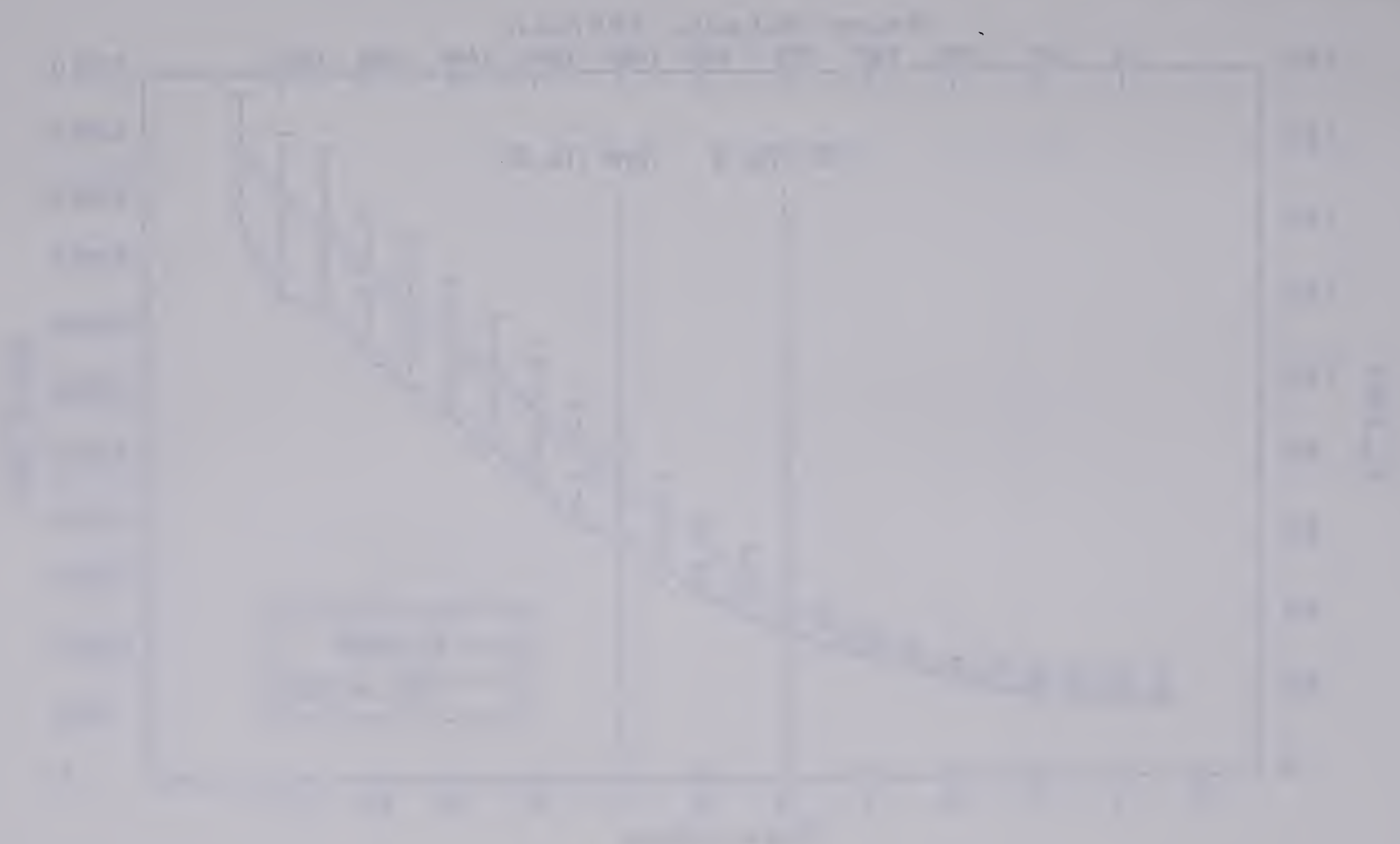


Figure 7 - The Pre Training Ventilation Volume and Carbon Dioxide Production during the Graded Exercise Test for the Sample of Thirty Eight Subjects



and carbon dioxide production while the power output at which the F_ECO_2 began to decrease would also be characterized by a large non-linear increase in the ventilation volume. Referring back to Figure 2 for the single subject, the F_EO_2 reached its minimum value after 2.5 minutes of exercise at a power output of 360 KPM/min and then began to increase. When the ventilation volume and carbon dioxide production curves in Figure 6 were examined, it was difficult to visualize the non-linear increases in these two variables at this power output. For the pooled values of the thirty-eight subjects in Figure 3, these non-linear increases should have occurred at 720 KPM/min. Once again, upon examining Figure 7, these non-linear increases were hard to identify. From Figures 4 and 5, it can be seen that the F_ECO_2 reached its maximum values at 720 KPM/min and 1,080 KPM/min for the one subject and entire sample of thirty-eight subjects respectively. However, when the curves in Figures 6 and 7 were examined, the exact locations of the large non-linear increases in the ventilation volumes that were supposed to occur at these power outputs were difficult to identify. Nevertheless, from the description of the $\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$, F_EO_2 and F_ECO_2 curves, it appears that the two thresholds described by Skinner and McLellan (101) correspond to the AT and TDMA described by Reinhard et al (90).

To summarize the results of this section, it can be said that there appear to be two reference points during the course of a graded exercise test on a bicycle ergometer prior to reaching the MEC. The first reference point is the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 reach a minimum. Some researchers have called this exercise intensity the Anaerobic Threshold (90) while others prefer to call it the Aerobic Threshold (64, 101). The second reference point is the power output at

which the $\dot{V}_E/\dot{V}CO_2$ ratio reaches a minimum and the F_ECO_2 reaches a maximum. This exercise intensity has been called the Threshold of Decompensated Metabolic Acidosis (90) while other researchers suggest calling it the Anaerobic Threshold (64, 101). Since these two reference points can be called by the same name (i.e. Anaerobic Threshold) a great deal of confusion can arise. To avoid this, the author of this study will henceforth call the first reference point as 'Threshold One' (Th.1) and the second reference point as 'Threshold Two' (Th.2).

SECTION C

In this section two sets of correlations are reported. In the first set, the inter-correlations between the six selected variables were computed at each of the following reference points: (1) the MEC (2) Th.1 and (3) Th.2. In the second set, the correlations between: (1) Th.1 and the MEC (2) Th.2 and the MEC and (3) Th.1 and Th.2 were computed for each of the six selected variables. In each of the two sets, correlations for the pre, mid and post tests were computed for the high fit, low fit and combined high and low fit categories of subjects. The critical 'r' value for significance on the pre test (n = 19) for the high or low fit categories was 0.456, while for the mid and post tests (n = 14) this value was 0.497. When the high and low fit categories were combined, the critical 'r' value for the pre test (n = 38) was 0.321, while for the mid and post tests (n = 28) this was 0.374. The raw data used for the computation of these correlations is given in Tables 35 to 52, Appendix C.

Inter-relationship between the Selected Variables at:

1) The Maximum Exercise Capacity

The correlation matrices of the selected variables at the MEC for the pre, mid and post tests are given in Tables 7 to 9 respectively. The only correlations to be consistently significant on all three test trials in all three categories under consideration were those between: (1) power output and time and (2) ventilation volume and $\dot{V}_E/\dot{V}O_2$ ratio. However, when only the combined category was considered, the absolute oxygen uptake was significantly related to the following variables on all three test trails: (1) power output (2) time (3) ventilation volume and (4) relative oxygen consumption.

2) Threshold One

The correlation matrices of the selected variables at Th.1 for the pre, mid and post tests are given in Tables 10 to 12 respectively. The results indicate that the power output, time, ventilation volume, absolute oxygen uptake and relative oxygen uptake were significantly inter-related on all three test trials in the high fit and combined categories. In the low fit category, all these variables were significantly related to each other on the pre and mid tests, but not on the post test. The $\dot{V}_E/\dot{V}O_2$ ratio was not consistently related to any of the five remaining variables on the three test trials in the three categories under consideration.

3) Threshold Two

The correlations reported in Tables 13 to 15 indicate that the power output, time, ventilation volume, absolute oxygen uptake and relative oxygen uptake were significantly related to each other on all three test trials in the three categories being considered. As was

Table 7 - Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Pre Test

Fitness Category	Variable	Power Out.	Time	Variable $\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=19)	Power Out.					
	Time	0.974[a]				
	$\dot{V}_E$	0.545[a]	0.654[a]			
	$\dot{V}O_2$ (abs)	0.641[a]	0.634[a]	0.542[a]		
	$\dot{V}O_2$ (rel)	0.141	0.167	0.254	0.457[a]	
	$\dot{V}_E/\dot{V}O_2$	0.270	0.307	0.456[a]	-0.014	-0.090
Low (n=19)	Power Out.					
	Time	0.957[a]				
	$\dot{V}_E$	0.437	0.409			
	$\dot{V}O_2$ (abs)	0.698[a]	0.640[a]	0.643[a]		
	$\dot{V}O_2$ (rel)	0.576[a]	0.619[a]	0.459[a]	0.550[a]	
	$\dot{V}_E/\dot{V}O_2$	0.019	0.048	0.795[a]	0.054	0.167
Combined (n=38)	Power Out.					
	Time	0.973[a]				
	$\dot{V}_E$	0.517[a]	0.555[a]			
	$\dot{V}O_2$ (abs)	0.729[a]	0.716[a]	0.590[a]		
	$\dot{V}O_2$ (rel)	0.499[a]	0.531[a]	0.372[a]	0.711[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.004	0.016	0.549[a]	-0.162	-0.225

a: correlation significant at the .05 level

Table 8 - Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Mid Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.986[a]				
	$\dot{V}_E$	0.507[a]	0.508[a]			
	$\dot{V}O_2$ (abs)	0.571[a]	0.762[a]	0.597[a]		
	$\dot{V}O_2$ (rel)	0.198	0.182	0.390	0.495	
	$\dot{V}_E/\dot{V}O_2$	-0.221	-0.228	0.540[a]	-0.349	-0.067
Low (n=14)	Power Out.					
	Time	0.979[a]				
	$\dot{V}_E$	0.147	0.146			
	$\dot{V}O_2$ (abs)	0.581[a]	0.615[a]	0.366		
	$\dot{V}O_2$ (rel)	0.444	0.399	0.001	0.629[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.147	-0.235	0.619[a]	-0.279	-0.377
Combined (n=28)	Power Out.					
	Time	0.983[a]				
	$\dot{V}_E$	0.352	0.345			
	$\dot{V}O_2$ (abs)	0.686[a]	0.705[a]	0.464[a]		
	$\dot{V}O_2$ (rel)	0.349	0.342	0.160	0.658[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.229	-0.227	0.530[a]	-0.406[a]	-0.400[a]

a: correlation significant at the .05 level

Table 9 - Inter-relationship between the Selected Variables at the Maximum Exercise Capacity on the Post Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.977[a]				
	$\dot{V}_E$	0.094	0.009			
	$\dot{V}O_2$ (abs)	0.735[a]	0.703[a]	0.515[a]		
	$\dot{V}O_2$ (rel)	-0.039	-0.031	0.539[a]	0.258	
	$\dot{V}_E/\dot{V}O_2$	-0.629[a]	-0.678[a]	0.504[a]	-0.476	0.273
Low (n=14)	Power Out.					
	Time	0.977[a]				
	$\dot{V}_E$	-0.016	0.041			
	$\dot{V}O_2$ (abs)	0.305	0.420	0.538[a]		
	$\dot{V}O_2$ (rel)	0.487	0.523[a]	0.221	0.303	
	$\dot{V}_E/\dot{V}O_2$	-0.282	-0.314	0.681[a]	-0.282	0.026
Combined (n=28)	Power Out.					
	Time	0.977[a]				
	$\dot{V}_E$	0.027	0.006			
	$\dot{V}O_2$ (abs)	0.590[a]	0.609[a]	0.472[a]		
	$\dot{V}O_2$ (rel)	0.251	0.276	0.225	0.378[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.496[a]	-0.532[a]	0.598[a]	-0.419[a]	-0.087

a: correlation significant at the .05 level

Table 10 - Inter-relationship between the Selected Variables at Threshold One on the Pre Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
	Power Out.					
	Time	0.966[a]				
	$\dot{V}_E$	0.909[a]	0.944[a]			
High (n=19)	$\dot{V}O_2$ (abs)	0.809[a]	0.835[a]	0.817[a]		
	$\dot{V}O_2$ (rel)	0.788[a]	0.754[a]	0.786[a]	0.783[a]	
	$\dot{V}_E/\dot{V}O_2$	0.273	0.293	0.424	-0.172	0.124
	Power Out.					
	Time	0.947[a]				
	$\dot{V}_E$	0.466[a]	0.570[a]			
Low (n=19)	$\dot{V}O_2$ (abs)	0.819[a]	0.853[a]	0.810[a]		
	$\dot{V}O_2$ (rel)	0.871[a]	0.910[a]	0.541[a]	0.797[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.582[a]	-0.466[a]	0.291	-0.319	-0.439
	Power Out					
	Time	0.960[a]				
	$\dot{V}_E$	0.779[a]	0.817[a]			
Combined (n=38)	$\dot{V}O_2$ (abs)	0.846[a]	0.854[a]	0.849[a]		
	$\dot{V}O_2$ (rel)	0.842[a]	0.810[a]	0.757[a]	0.842[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.122	-0.065	0.294	-0.249	-0.136

a: correlation significant at the .05 level

Table 11 - Inter-relationship between the Selected Variables at Threshold One on the Mid Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.974[a]				
	$\dot{V}_E$	0.861[a]	0.896[a]			
	$\dot{V}O_2$ (abs)	0.934[a]	0.925[a]	0.851[a]		
	$\dot{V}O_2$ (rel)	0.883[a]	0.819[a]	0.819[a]	0.855[a]	
	$\dot{V}_E/\dot{V}O_2$	0.236	0.313	0.613[a]	0.109	0.271
Low (n=14)	Power Out.					
	Time	0.951[a]				
	$\dot{V}_E$	0.599[a]	0.536[a]			
	$\dot{V}O_2$ (abs)	0.627[a]	0.540[a]	0.720[a]		
	$\dot{V}O_2$ (rel)	0.671[a]	0.590[a]	0.590[a]	0.753[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.051	-0.032	0.422	-0.319	-0.186
Combined (n=28)	Power Out.					
	Time	0.970[a]				
	$\dot{V}_E$	0.809[a]	0.802[a]			
	$\dot{V}O_2$ (abs)	0.877[a]	0.840[a]	0.838[a]		
	$\dot{V}O_2$ (rel)	0.846[a]	0.793[a]	0.766[a]	0.863[a]	
	$\dot{V}_E/\dot{V}O_2$	0.045	0.081	0.458[a]	-0.096	-0.014

a: correlation significant at the .05 level

Table 12 - Inter-relationship between the Selected Variables at Threshold One the Post Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.949[a]				
	$\dot{V}_E$	0.831[a]	0.748[a]			
	$\dot{V}O_2$ (abs)	0.884[a]	0.825[a]	0.897[a]		
	$\dot{V}O_2$ (rel)	0.696[a]	0.667[a]	0.788[a]	0.714[a]	
	$\dot{V}_E/\dot{V}O_2$	0.317	0.233	0.653[a]	0.257	0.547[a]
Low (n=14)	Power Out.					
	Time	0.940[a]				
	$\dot{V}_E$	0.356	0.447			
	$\dot{V}O_2$ (abs)	0.587[a]	0.610[a]	0.630[a]		
	$\dot{V}O_2$ (rel)	0.724[a]	0.634[a]	0.089	0.418	
	$\dot{V}_E/\dot{V}O_2$	-0.166	-0.079	0.585[a]	-0.259	-0.324
Combined (n=28)	Power Out.					
	Time	0.958[a]				
	$\dot{V}_E$	0.669[a]	0.658[a]			
	$\dot{V}O_2$ (abs)	0.802[a]	0.783[a]	0.850[a]		
	$\dot{V}O_2$ (rel)	0.793[a]	0.746[a]	0.626[a]	0.708[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.023	-0.011	0.525[a]	0.004	0.050

a: correlation significant at the .05 level

Table 13 - Inter-relationship between the Selected Variables at Threshold Two on the Pre Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
	Power Out.					
	Time	0.986[a]				
	$\dot{V}_E$	0.898[a]	0.892[a]			
High (n=19)	$\dot{V}O_2$ (abs)	0.772[a]	0.754[a]	0.874[a]		
	$\dot{V}O_2$ (rel)	0.657[a]	0.691[a]	0.820[a]	0.804[a]	
	$\dot{V}_E/\dot{V}O_2$	0.407	0.424	0.410	-0.089	0.186
	Power Out.					
	Time	0.987[a]				
	$\dot{V}_E$	0.686[a]	0.731[a]			
Low (n=19)	$\dot{V}O_2$ (abs)	0.846[a]	0.865[a]	0.859[a]		
	$\dot{V}O_2$ (rel)	0.907[a]	0.919[a]	0.608[a]	0.774[a]	
	$\dot{V}_E/\dot{V}O_2$	-0.026	0.046	0.569[a]	0.077	-0.058
	Power Out.					
	Time	0.985[a]				
	$\dot{V}_E$	0.848[a]	0.860[a]			
Combined (n=38)	$\dot{V}O_2$ (abs)	0.845[a]	0.836[a]	0.890[a]		
	$\dot{V}O_2$ (rel)	0.810[a]	0.811[a]	0.784[a]	0.853[a]	
	$\dot{V}_E/\dot{V}O_2$	0.125	0.175	0.379[a]	-0.079	-0.019

a: correlation significant at the .05 level

Table 14 - Inter-relationship between the Selected Variables at Threshold Two on the Mid Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.983[a]				
	$\dot{V}_E$	0.899[a]	0.913[a]			
	$\dot{V}O_2$ (abs)	0.937[a]	0.935[a]	0.927[a]		
	$\dot{V}O_2$ (rel)	0.829[a]	0.819[a]	0.904[a]	0.841[a]	
	$\dot{V}_E/\dot{V}O_2$	0.594[a]	0.626[a]	0.808[a]	0.535[a]	0.729[a]
Low (n=14)	Power Out.					
	Time	0.965[a]				
	$\dot{V}_E$	0.777[a]	0.820[a]			
	$\dot{V}O_2$ (abs)	0.766[a]	0.766[a]	0.790[a]		
	$\dot{V}O_2$ (rel)	0.587[a]	0.646[a]	0.566[a]	0.729[a]	
	$\dot{V}_E/\dot{V}O_2$	0.178	0.246	0.516[a]	-0.114	-0.081
Combined (n=28)	Power Out.					
	Time	0.977[a]				
	$\dot{V}_E$	0.835[a]	0.866[a]			
	$\dot{V}O_2$ (abs)	0.883[a]	0.883[a]	0.855[a]		
	$\dot{V}O_2$ (rel)	0.760[a]	0.766[a]	0.740[a]	0.842[a]	
	$\dot{V}_E/\dot{V}O_2$	0.175	0.235	0.520[a]	0.013	0.026

a: correlation significant at the .05 level

Table 15 - Inter-relationship between the Selected Variables at Threshold Two on the Post Test

Fitness Category	Variable	Power Out.	Time	$\dot{V}_E$	$\dot{V}O_2$ (abs)	$\dot{V}O_2$ (rel)
High (n=14)	Power Out.					
	Time	0.991[a]				
	$\dot{V}_E$	0.846[a]	0.850[a]			
	$\dot{V}O_2$ (abs)	0.937[a]	0.949[a]	0.921[a]		
	$\dot{V}O_2$ (rel)	0.671[a]	0.705[a]	0.867[a]	0.767[a]	
	$\dot{V}_E/\dot{V}O_2$	0.424	0.416	0.786[a]	0.487	0.755[a]
Low (n=14)	Power Out.					
	Time	0.980[a]				
	$\dot{V}_E$	0.679[a]	0.595[a]			
	$\dot{V}O_2$ (abs)	0.868[a]	0.805[a]	0.879[a]		
	$\dot{V}O_2$ (rel)	0.821[a]	0.820[a]	0.571[a]	0.722[a]	
	$\dot{V}_E/\dot{V}O_2$	0.001	-0.071	0.647[a]	0.210	0.023
Combined (n=28)	Power Out.					
	Time	0.987[a]				
	$\dot{V}_E$	0.788[a]	0.759[a]			
	$\dot{V}O_2$ (abs)	0.915[a]	0.903[a]	0.895[a]		
	$\dot{V}O_2$ (rel)	0.750[a]	0.777[a]	0.720[a]	0.784[a]	
	$\dot{V}_E/\dot{V}O_2$	0.169	0.130	0.658[a]	0.257	0.246

a: correlation significant at the .05 level

the case at Th.1, the $\dot{V}_E/\dot{V}O_2$ ratio was not consistently related to any of the five remaining variables on the three test trials in the three categories under consideration. However, when only the combined category was considered, the $\dot{V}_E/\dot{V}O_2$ ratio was significantly related to the ventilation volume on all three test trials.

<u>Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Selected Variables</u>

The inter-correlations between the MEC, Th.1 and Th.2 for the six selected variables are given in Tables 16 - 21 respectively. The correlations for each of these variables are considered separately below.

1) Power Output

The results in Table 16 indicate that the correlation between the power output at the MEC and Th.1 was not consistently sifnificant on all three test trials in all three categories being considered. In contrast, the correlation between the power output at the MEC and Th.2 was significant on all three test trials in all three categories. The correlation between the power output at Th.1 and Th.2 was significant on all three test trials only in the combined category.

2) Time

The results in Table 17 indicate that the inter-relationship between the MEC, Th.1 and Th.2 for the time variable was not consistently significant on all three test trials in all three categories. However, when only the combined category was considered, the correlation between: (1) the time taken to attain the MEC and Th.2 and (2) the time taken to attain Th.1 and Th.2 was significant on all three test

Table 16 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Power Output on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1]		MID TEST[2]		POST TEST[2]	
		MEC	Th.1	MEC	Th.1	MEC	Th.1
High	Th.1	0.414		0.161		0.269	
	Th.2	0.633[a]	0.262	0.556[a]	0.415	0.616[a]	0.401
Low	Th.1	0.469[a]		0.456		0.370	
	Th.2	0.527[a]	0.547[a]	0.625[a]	0.415	0.511[a]	0.326
Combined	Th.1	0.532[a]		0.309		0.347	
	Th.2	0.667[a]	0.507[a]	0.602[a]	0.489[a]	0.597[a]	0.460[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

Table 17 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Time on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1] MEC	PRE TEST[1] Th.1	MID TEST[2] MEC	MID TEST[2] Th.1	POST TEST[2] MEC	POST TEST[2] Th.1
High	Th.1	0.519[a]		0.255		0.260	
	Th.2	0.628[a]	0.230	0.613[a]	0.420	0.601[a]	0.420
Low	Th.1	0.529[a]		9.410		0.368	
	Th.2	0.509[a]	0.473[a]	0.487	0.333	0.564[a]	0.448
Combined	Th.1	0.589[a]		0.365		0.346	
	Th.2	0.654[a]	0.431[a]	0.584[a]	0.463[a]	0.604[a]	0.520[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

trials.

3) Ventilation Volume

As was the case for the time taken to attain the MEC, Th.1 and Th.2, the only correlations (Table 18) to be significant on all three test trials were those between: (1) the MEC and Th.2 and (2) Th.1 and Th.2 in the combined category.

4) Absolute Oxygen Uptake

The results in Table 19 indicate that the correlation between the absolute oxygen uptake at the MEC (i.e. maximum oxygen uptake, l/min) and Th.2 was significant on all three test trials in all three categories. The correlation between the absolute oxygen uptake at the MEC and Th.1 as well as that between Th.1 and Th.2 was significant on each test trial only in the combined category.

5) Relative Oxygen Uptake

The overall results of the correlations reported in Table 20 for the relative oxygen uptake at the three reference points were similar to those reported in Table 19 for the absolute oxygen uptake - i.e. the correlation between the relative oxygen uptake at the MEC (i.e. maximum oxygen uptake, ml/kg/min) and Th.2 was significant in each case, whereas the correlations between: (1) the MEC and Th.1 and (2) the MEC and Th.2 were significant only in the combined category.

6) $\dot{V}_E/\dot{V}O_2$ Ratio

The correlations reported in Table 21 indicate that the $\dot{V}_E/\dot{V}O_2$ ratios at Th.1 and Th.2 were significantly related to each other in each case. The correlations between the $\dot{V}_E/\dot{V}O_2$ ratios at: (1) the

Table 18 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Ventilation Volume on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1]		MID TEST[2]		POST TEST[2]	
		MEC	Th.1	MEC	Th.1	MEC	Th.1
High	Th.1	0.498[a]		0.454		0.340	
	Th.2	0.404	0.384	0.578[a]	0.667[a]	0.337	0.569[a]
Low	Th.1	0.482[a]		0.515[a]		0.244	
	Th.2	0.234	0.354	0.113	0.071	0.618[a]	0.195
Combined	Th.1	0.512[a]		0.435[a]		0.256	
	Th.2	0.370[a]	0.485[a]	0.339[a]	0.547[a]	0.440[a]	0.472[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

Table 19 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Absolute Oxygen Consumption on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1]		MID TEST[2]		POST TEST[2]	
		MEC	Th.1	MEC	Th.1	MEC	Th.1
High	Th.1	0.641[a]		0.594[a]		0.601[a]	
	Th.2	0.662[a]	0.476[a]	0.809[a]	0.468	0.611[a]	0.433
Low	Th.1	0.490[a]		0.334		0.217	
	Th.2	0.554[a]	0.574[a]	0.639[a]	0.083	0.714[a]	0.213
Combined	Th.1	0.694[a]		0.598[a]		0.526[a]	
	Th.2	0.733[a]	0.634[a]	0.789[a]	0.485[a]	0.686[a]	0.449[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

Table 20 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Relative Oxygen Consumption on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1] MEC	PRE TEST[1] Th.1	MID TEST[2] MEC	MID TEST[2] Th.1	POST TEST[2] MEC	POST TEST[2] Th.1
High	Th.1	0.601[a]		0.488[a]		0.371	
	Th.2	0.525[a]	0.330	0.945[a]	0.439	0.749[a]	0.404
Low	Th.1	0.368		0.489		0.530[a]	
	Th.2	0.483[a]	0.536[a]	0.658[a]	0.298	0.791[a]	0.405
Combined	Th.1	0.737[a]		0.671[a]		0.643[a]	
	Th.2	0.766[a]	0.653[a]	0.851[a]	0.596[a]	0.836[a]	0.593[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

Table 21 - Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the $\dot{V}_E/\dot{V}O_2$ Ratio on the Pre, Mid and Post Tests

Fitness Category	Reference Point	PRE TEST[1]		MID TEST[2]		POST TEST[2]	
		MEC	Th.1	MEC	Th.1	MEC	Th.1
High	Th.1	0.474[a]		0.263		0.211	
	Th.2	0.603[a]	0.829[a]	0.381	0.916[a]	0.434	0.791[a]
Low	Th.1	0.696[a]		0.450		0.737[a]	
	Th.2	0.511[a]	0.703[a]	0.433	0.819[a]	0.627[a]	0.607[a]
Combined	Th.1	0.575[a]		0.380[a]		0.499[a]	
	Th.2	0.552[a]	0.771[a]	0.494[a]	0.831[a]	0.556[a]	0.713[a]

1:n = 19 for High and Low Fit Categories on Pre Test, n = 38 for Combined Category on Pre Test

2:n = 14 for High and Low Fit Categories on Mid and Post Tests, n = 28 for Combined Category on Mid and Post Tests

a:Correlation significant at the .05 level

MEC and Th.1 and (2) the MEC and Th.2 were significant on all three test trials only in the combined category.

SECTION D

Interpretation of the Three Way Analysis of Variance

Since two subjects were unable to complete the study, the number of subjects per treatment group in both the fitness categories was unequal. A three-way analysis of variance was run on this data using unequal cell sizes - no post hoc comparisons were computed for these analyses. Subsequently, a three-way analysis of variance was computed by equalizing the number of subjects in each treatment group in the two fitness categories. This was done by excluding the data of the subjects of the same rank order in the groups that had the extra subjects in the two fitness categories - i.e. the data for subjects ranked No. 2 in the CG, TG and ITG in the high fit category and the data of the subjects of the same rank order in the CG, ATG and ITG in the low fit category was excluded. Post hoc comparisons using the Scheffe technique (132) were computed for those 'F' ratios that proved to be significant on the Greenhouse-Geisser conservative test (132). Since the results of the analyses of variance using equal and unequal cell numbers were the same, the results using the equal cell sizes are reported here. The raw data used for computing these analyses of variance is given in Tables 35 to 68, Appendix C. The complete summaries of the analyses of variance are given in Tables 88 to 121, Appendix D.

Before proceeding to present the results of these analyses, perhaps a few words should be said at this stage about the interpretation of the three-way analysis of variance. Keppel (63) has suggested that the researcher first examine the triple (ABC) interaction term in the summary of the analysis of variance. If this 'F' ratio is significant, the next logical step is to examine the simple two-way interactions - i.e. A x B at each level of C, A x C at each level of B and B x C at each level of A. If the triple interaction is insignificant, then the logical step is to assess the two-way interactions - i.e. A x B, A x C or B x C. The reason given for this suggestion is that in the presence of the significant triple interaction, any results that may be interpreted from the two-way interactions will be incomplete - a certain amount of ambiguity would still exist because of the significant triple interaction. For the same reason, he also suggests examining the two-way interactions for significance before examining the main effects of each factor.

In this study, for each of the variables selected at Th.1, Th.2 and the MEC, the triple interaction term was insignificant. This indicated that the two fitness categories reacted similarly to the four treatment conditions thereby accepting the null hypothesis that the high and low fit categories would show similar changes as a result of the three training intensities. In order to make comparisons between the high and low fit categories and to assess the effects of the four treatment conditions on the selected variables at these three reference points, the AC and BC interaction terms were examined respectively. It should be noted that when the two-way interactions are examined, the levels of the factor not included in that particular interaction term

are collapsed. Hence, for the AC interaction, the four levels of B are collapsed thereby basing the comparisons on a sample size of sixteen subjects (equal cell sizes). For the BC interaction, the two levels of A are collapsed thereby basing the comparisons on a sample size of eight subjects. The results of these two interactions and the three main effects for each of the variables selected at Th.1, Th.2 and the MEC are reported in Tables 22 to 31. The probability levels of the interaction terms and main effects indicated in these tables are those obtained using the degrees of freedom on the basis of the analysis of variance and not the Greenhouse-Geisser conservative test. The 'F' ratios that are significant at the .05 level on the basis of the analysis of variance but not on the basis of the conservative test are marked with an asterisk*. The critical values of the 'F' ratios required for significance on the conservative test are reported in Table 87, Appendix D.

<u>Comparison between the High and Low Fit Categories on the Pre, Mid and Post Tests for the Selected Variables at:</u>

1) The Maximum Exercise Capacity

A comparison between the high and low fit categories for the selected variables at the MEC on the three test trials is given in Table 22. No significant differences were observed between the two fitness categories for the power output, time and ventilation volume at the MEC for the three test trials. The absolute and relative maximum oxygen uptakes were significantly greater in the high fit category than in the low fit category for all three tests. In contrast, the $\dot{V}_E/\dot{V}O_2$

Table 22 - Comparison between the High and Low Fit Categories for Selected Variables at the Maximum Exercise Capacity on the Pre, Mid and Post Tests

Variable	Category	Pre	Mid	Post
AC:p=.866	High	1766	1924^{1}	$2093^{2,3}$
Pow. Out., KPM/min				
A:p=.049 C:p=.000	Low	1620	1789^{1}	$1969^{2,3}$
AC:p=.921	High	10.5	11.4^{1}	$12.3^{2,3}$
Time, mins				
A:p=.048 C:p=.000	Low	9.7	10.7^{1}	$11.6^{2,3}$
AC:p=.425	High	127.2	140.4^{1}	144.1^{3}
$\dot{V}_E$, l/min				
A:p=.345 C:p=.000	Low	115.8	135.7^{1}	140.6^{3}
AC:p=.004	High	3.48	3.69^{3}	3.69^{3}
$\dot{V}O_2$, l/min				
A:p=.001 C:p=.000	Low	2.81	3.18^{1}	3.32^{3}
AC:p=.004	High	$^{a}46.0$	$^{a}48.8^{1}$	$^{a}49.0^{3}$
$\dot{V}O_2$,ml/kg/min				
A:p=.000 C:p=.000	Low	35.5	40.5^{1}	$42.5^{2,3}$
AC:p=.839	High	$^{a}36.7$	$^{a}38.3$	39.3
$\dot{V}_E/\dot{V}O_2$				
A:p=.008 C:p=.132	Low	41.2	42.4	42.6

a = High-Low)
1 = Mid-Pre) F values significant at the .05 level
2 = Post-Mid)
3 = Post-Pre)

ratio was significantly lower in the high fit category than in the low fit category for the pre and mid tests only.

2) Threshold One

A comparison between the two fitness categories for the selected variables at Th.1 for the three test trials is given in Table 23. The power output was significantly higher in the high fit category only on the post test while the time was significantly higher in these subjects on the mid and post tests. The absolute oxygen consumption was significantly higher in the high fit subjects on the pre and mid tests while the relative value was higher on all three test trials. No significant differences between the two fitness categories were observed for the ventilation volume and $\dot{V}_E/\dot{V}O_2$ ratio at this threshold.

3) Threshold Two

A comparison between the two fitness categories for the mean values of the selected variables at Th.2 is given in Table 24. No significant differences were observed between the two fitness categories for the ventilation volume and $\dot{V}_E/\dot{V}O_2$ ratio. The power output at this threshold was significantly higher in the high fit category than in the low fit category for the mid test only, while the time was significantly higher in these subjects for the mid and post tests. The absolute and relative oxygen uptakes were significantly higher in the high fit category on all three test trials.

The comparisons between the two fitness categories for the selected variables at Th.1 and Th.2 expressed as percentages of the corresponding variables at the MEC are given in Tables 25 and 26 respectively. No significant differences between the two fitness categories were observed

Table 23 - Comparison between the High and Low Fit Categories for Selected Variables at Threshold One on the Pre, Mid and Post Tests

Variable	Category	Pre	Mid	Post
AC:p=.370	High	754	799	$^{a}888^{2,3}$
Pow. Out., KPM/min				
A:p=.015 C:p=.000	Low	641	675	720^{3}
AC:p=.351	High	4.8	$^{a}5.3^{1}$	$^{a}5.7^{2,3}$
Time, mins				
A:p=.021 C:p=.000	Low	4.3	4.4	$4.9^{2,3}$
AC:p=.750	High	36.6	39.1	40.2^{3}
$\dot{V}_E$, l/min				
A:p=.043 C:p=.000	Low	30.8	34.0	35.8^{3}
AC:p=.308	High	$^{a}1.58$	$^{a}1.63$	1.66
$\dot{V}O_2$, l/min				
A:p=.005 C:p=.001	Low	1.26	1.34	1.44^{3}
AC:p=.359	High	$^{a}20.8$	$^{a}21.7$	$^{a}22.0$
$\dot{V}O_2$, ml/kg/min				
A:p=.001 C:p=.001	Low	15.9	17.1	18.3^{3}
AC:p=.590	High	23.3	23.9	24.2
$\dot{V}_E/\dot{V}O_2$				
A:p=.079 C:p=.234	Low	24.7	25.4	25.0

a = High-Low)
1 = Mid-Pre) F values significant at the .05 level
2 = Post-Mid)
3 = Post-Pre)

Table 24 - Comparison between the High and Low Fit Categories for Selected Variables at Threshold Two on the Pre, Mid and Post Tests

Variable	Category	Pre	Mid	Post
AC:p=.975	High	1249	[a]1406[1]	1530[2,3]
Pow. Out., KPM/min				
A:p=.019 C:p=.000	Low	1057	1203[1]	1338[2,3]
AC:p=.745	High	7.6	[a]8.6[1]	[a]9.3[2,3]
Time, mins				
A:p=.023 C:p=.000	Low	6.7	7.5[1]	8.2[2,3]
AC:p=.964	High	64.4	76.0[1]	81.5[3]
$\dot{V}_E$, l/min				
A:p=.071 C:p=.000	Low	54.4	66.9[1]	71.2[3]
AC:p=.743	High	[a]2.45	[a]2.72[1]	[a]2.81[3]
$\dot{V}O_2$, l/min				
A:p=.004 C:p=.000	Low	1.93	2.26[1]	2.37[3]
AC:p=.850	High	[a]32.6	[a]36.1[1]	[a]37.6[3]
$\dot{V}O_2$, ml/kg/min				
A:p=.000 C:p=.000	Low	24.4	28.1[1]	30.1[3]
AC:p=.520	High	26.3	27.9	28.8[3]
$\dot{V}_E/\dot{V}O_2$				
A:p=.059 C:p=.001	Low	28.2	30.0	29.7

a = High-Low)
1 = Mid-Pre) F values significant at the .05 level
2 = Post-Mid)
3 = Post-Pre)

Table 25 - Comparison between the High and Low Fit Categories for Selected Variables at Threshold One expressed as a Percentage of the Maximum Exercise Capacity on the Pre, Mid and Post Tests

Variable	Category	Pre	Mid	Post
AC:p=.740	High	42.8	41.9	42.7
Pow. Out., KPM/min				
A:p=.140 C:p=.619	Low	39.5	38.1	37.6
AC:p=.402	High	46.2	46.0	46.4
Time, mins				
A:p=.198 C:p=.352	Low	44.8	41.8	42.5
AC:p=.776	High	29.0	28.0	28.0
$\dot{V}_E$, l/min				
A:p=.244 C:p=.188	Low	27.8	25.4	25.8
AC:p=.803	High	45.2	44.2	44.9
$\dot{V}O_2$, l/min				
A:p=.713 C:p=.300	Low	45.1	42.8	43.8
AC:p=.931	High	64.2	63.3	62.1
$\dot{V}_E/\dot{V}O_2$				
A:p=.088 C:p=.277	Low	61.2	60.6	58.3

Table 26 - Comparison between the High and Low Fit Categories for Selected Variables at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity on the Pre, Mid and Post Tests

Variable	Category	Pre	Mid	Post
AC:p=.924	High	70.7	73.4	72.8
Pow. Out., KPM/min				
A:p=.095 C:p=.296	Low	65.2	67.3	68.1
AC:p=.736	High	72.5	75.6	75.6
Time, mins				
A:p=.121 C:p=.190	Low	69.0	69.8	70.8
AC:p=.465	High	51.1	54.4	56.6
$\dot{V}_E$, l/min				
A:p=.182 C:p=.143	Low	48.7	49.6	50.0
AC:p=.017*	High	70.1	73.5	76.2
$\dot{V}O_2$, l/min				
A:p=.285 C:p=.058	Low	69.1	70.0	70.9
AC:p=.954	High	72.6	73.6	73.6
$\dot{V}_E/\dot{V}O_2$				
A:p=.219 C:p=.742	Low	69.8	71.4	70.4

* = F value insignificant at the .05 level on the basis of the Greenhouse-Geisser conservative test

for any of these variables at the two thresholds for the pre, mid or post tests.

The Effect of the Four Treatments on the Selected Variables at:

1) The Maximum Exercise Capacity

The effect of the four treatments on the means of the selected variables at the MEC is reported in Table 27. The pre vs. post test comparisons revealed that there was a significant increase in each of these variables except the $\dot{V}_E/\dot{V}O_2$ ratio in the three training groups, while no significant change was observed in the CG for any of these variables.

2) Threshold One

The mean values of the selected variables at Th.1 for the pre, mid and post tests are compared in Table 28. The pre vs. post test comparisons revealed that the power output, time and expired volume increased significantly in all three training groups. The absolute and relative oxygen uptakes increased significantly only in the TG and ATG. No significant change was observed in the $\dot{V}_E/\dot{V}O_2$ ratio in any of the training groups. The CG showed no significant difference between the three test trials for any of the variables except the ventilation volume and time which increased significantly.

3) Threshold Two

The mean values of the selected variables at Th.2 for the three test trials are compared in Table 29. The pre vs. post test comparisons revealed that with the exception of the $\dot{V}_E/\dot{V}O_2$ ratio, all the other variables showed a significant increase in all three training groups.

Table 27 - Effect of the Four Treatments on the Selected Variables at the Maximum Exercise Capacity in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.000	CG	1710	1688	1755	BC:p=.001	CG	3.11	3.14	3.11
Pow. Out., KPM/min	TG	1643	1823^{1}	$^{a}2003^{2,3}$	$\dot{V}O_2$, 1/min	TG	3.11	$^{a}3.49^{1}$	$^{a}3.56^{3}$
B:p=.038	ATG	1665	$^{b}1890^{1}$	$^{b}2160^{2,3}$	B:p=.088	ATG	3.00	3.34^{1}	$^{b}3.53^{2,3}$
C:p=.000	ITG	1755	$^{c,e}2025^{1}$	$^{c,e}2205^{2,3}$	C:p=.000	ITG	$^{f}3.35$	$^{c,f}3.76^{1}$	$^{c}3.81^{3}$
BC:p=.000	CG	10.1	10.1	10.3	BC:p=.002	CG	41.3	42.0	41.9
Time, mins	TG	9.8	10.9^{1}	$^{a}11.8^{2,3}$	$\dot{V}O_2$, ml/kg/min	TG	39.9	44.8^{1}	$^{a}45.8^{3}$
B:p=.012	ATG	10.0	$^{b}11.1^{1}$	$^{b}12.6^{2,3}$	B:p=.387	ATG	40.4	45.3^{1}	$^{b}48.3^{2,3}$
C:p=.000	ITG	10.5	$^{c,e,f}12.3^{1}$	$^{c,e}13.1^{2,3}$	C:p=.000	ITG	41.5	$^{c}46.3^{1}$	$^{c}47.1^{3}$
BC:p=.070	CG	123.7	127.0	126.3	BC;p=.850	CG	39.8	41.0	41.2
$\dot{V}_E$, 1/min	TG	117.1	140.4^{1}	141.5^{3}	$\dot{V}_E/\dot{V}O_2$	TG	38.1	41.0	40.0
B:p=.488	ATG	123.9	142.1^{1}	152.5^{3}	B:p=.117	ATG	42.3	41.5	43.5
C:p=.000	ITG	121.3	142.9^{1}	149.0^{3}	C:p=.132	ITG	35.7	38.0	39.0^{3}

1 = Mid-Pre   a = TG-CG   d = ATG-TG)

2 = Post-Mid   b = ATG-CG   e = ITG-TG)   F values significant at the .05 level

3 = Post-Pre   c = ITG-CG   f = ITG-ATG)

Table 28 - Effect of the Four Treatments on the Selected Variables at Threshold One in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.707	CG	675	720	743	BC:p=.066	CG	1.33	1.35	1.41
Pow. Out., KPM/min	TG	653	720	$810^{2,3}$	$\dot{V}O_2$, 1/min	TG	1.39	1.43	$1.66^{2,3}$
B:p=.694	ATG	698	742	810^{3}	B:p=.172	ATG	1.35	1.47^{1}	1.49^{3}
C:p=.000	ITG	765	765	$855^{2,3}$	C:p=.001	ITG	1.59	1.70^{1}	1.63
BC:p=.830	CG	4.5	4.7	4.9^{3}	BC:p=.066	CG	17.5	18.1	18.7
Time, mins	TG	4.4	4.8	$5.3^{2,3}$	$\dot{V}O_2$, ml/kg/min	TG	17.8	18.2	$21.3^{2,3}$
B:p=.697	ATG	4.6	4.9	$5.3^{2,3}$	B:p=.525	ATG	18.3	20.0^{1}	20.4^{3}
C:p=.000	ITG	4.9	5.1	$5.5^{2,3}$	C:p=.001	ITG	19.9	21.2	20.3
BC:p=.397	CG	31.7	33.8	35.5^{3}	BC:p=.687	CG	24.1	24.9	25.4
$\dot{V}_E$, 1/min	TG	33.4	34.1	$39.3^{2,3}$	$\dot{V}_E/\dot{V}O_2$	TG	24.1	24.1	23.7
B:p=.365	ATG	32.7	37.0^{1}	36.8^{3}	B:p=.652	ATG	24.5	25.6	24.8
C:p=.000	ITG	37.1	${}^{c,e}41.4^{1}$	40.5^{3}	C:p=.234	ITG	23.4	24.2	24.6

1 = Mid-Pre   a = TG-CG   d = ATG-TG)

2 = Post-Mid   b = ATG-CG   e = ITG-TG)   F values significant at the .05 level

3 = Post-Pre   c = ITG-CG   f = ITG-ATG)

Table 29 - Effect of the Four Treatments on the Selected Variables at Threshold Two in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.000	CG	1148	1148	1103	BC:p=.000	CG	2.12	2.14	2.06
Pow. Out., KPM/min	TG	1238	$^{a}1395^{1}$	$^{a}1485^{3}$	$\dot{V}O_2$, 1/min	TG	2.42	$^{a}2.62^{3}$	$^{a}2.73^{3}$
B:p=.089	ATG	$^{d}1013$	1305^{1}	$^{b}1530^{2,3}$	B:p=.085	ATG	$^{d}1.90$	2.45^{1}	$^{b}2.70^{2,3}$
C:p=.000	ITG	$^{f}1215$	$^{c}1373^{1}$	$^{c}1620^{2,3}$	C:p=.000	ITG	$^{f}2.31$	$^{c}2.68^{1}$	$^{c}2.87^{2,3}$
BC:p=.000	CG	7.1	7.2	6.9	BC:p=.000	CG	28.6	28.5	27.6
Time, mins	TG	7.7	$^{a}8.5^{1}$	$^{a}9.1^{2,3}$	$\dot{V}O_2$, ml/kg/min	TG	31.0	$^{a}33.5^{1}$	$^{a}35.1^{3}$
B:p=.106	ATG	$^{d}6.4$	8.1^{1}	$^{b}9.4^{2,3}$	B:p=.287	ATG	$^{d}25.8$	$^{b}33.3^{1}$	$^{b}37.2^{2,3}$
C:p=.000	ITG	7.4	$^{c}8.4^{1}$	$^{c}9.7^{2,3}$	C:p=.000	ITG	28.6	33.2^{1}	$^{c}35.6^{2,3}$
BC:p=.000	CG	58.3	62.7	59.0	BC:p=.258	CG	27.4	28.9	28.5
$\dot{V}_E$, 1/min	TG	68.3	74.7	$^{a}78.9^{3}$	$\dot{V}_E/\dot{V}O_2$	TG	28.5	28.6	28.8
B:p=.210	ATG	50.4	73.0^{1}	$^{b}81.3^{2,3}$	B:p=.734	ATG	27.0	30.3^{1}	30.1^{3}
C:p=.000	ITG	60.6	75.3^{1}	$^{c}86.2^{2,3}$	C:p=.001	ITG	26.1	28.0	29.7^{3}

1 = Mid-Pre   a = TG-CG   d = ATG-TG)

2 = Post-Mid   b = ATG-CG   e = ITG-TG)   F values significant at the .05 level

3 = Post-Pre   c = ITG-CG   f = ITG-ATG)

The $\dot{V}_E/\dot{V}O_2$ ratio increased significantly only in the ATG and ITG. No significant change was observed in the CG for any of these variables.

The mean values of the selected variables at Th.1 and Th.2 expressed as percentages of the corresponding variables at the MEC are compared in Tables 30 and 31 respectively. No significant change was observed in any of these variables at Th.1 in the four subgroups. At Th.2 a significant increase was observed in the ventilation volume in the ATG and ITG but not in the TG or CG. None of the other variables at this threshold increased significantly in any of the groups.

<u>Effect of the Four Treatments on the Ventilation Volume, Oxygen Consumption, Carbon Dioxide Production, $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio and F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output</u>

The mean values of the above variables at the pre training MEC power output for the pre, mid and post tests are compared in Table 32. A significant decrease was observed in each of these variables in the three training groups, while no significant change was observed in the CG for any of these variables.

Table 30 - Effect of the Four Treatments on the Selected Variables at Threshold One expressed as a Percentage of the Maximum Exercise Capacity in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.122	CG	39.5	42.9	41.9	BC:p=.036*	CG	42.8	43.6	45.4
Pow. Out., KPM/min	TG	40.0	39.8	42.5	$\dot{V}O_2$, l/min	TG	45.0	40.8	46.8
B:p=.957	ATG	41.6	39.4	37.5	B:p=.968	ATG	45.1	44.3	42.4
C:p=.619	ITG	43.5	37.8	38.7	C:p=.300	ITG	47.8	45.2	42.8
BC:p=.193	CG	44.7	46.0	47.6					
Time, mins	TG	45.0	43.9	45.8					
B:p=.875	ATG	45.4	44.3	42.3					
C:p=.352	ITG	46.9	41.3	42.2					
BC:p=.179	CG	26.4	26.9	28.0	BC:p=.617	CG	61.2	61.8	61.9
$\dot{V}_E$, l/min	TG	28.7	24.3	27.8	$\dot{V}_E/\dot{V}O_2$	TG	63.8	59.3	58.3
B:p=.518	ATG	26.7	26.6	24.4	B:p=.230	ATG	59.7	62.3	57.2
C:p=.188	ITG	31.8	29.0	27.4	C:p=.277	ITG	66.1	64.3	63.6

1 = Mid-Pre   a = TG-CG   d = ATG-TG)

2 = Post-Mid   b = ATG-CG   e = ITG-TG)   F values significant at the .05 level

3 = Post-Pre   c = ITG-CG   f = ITG-ATG)

* = F Value not significant at the .05 level on the basis of the Greenhouse - Geisser conservative test

Table 31 - Effect of the Four Treatments on the Selected Variables at Threshold Two expressed as a Percentage of the Maximum Exercise Capacity in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.092	CG	66.8	67.6	62.3	BC:p=.017*	CG	67.9	67.7	65.4
Pow. Out., KPM/min	TG	74.9	76.4	75.0	$\dot{V}O_2$, 1/min	TG	77.5	74.7	76.8
B:p=.134	ATG	60.4	68.7	70.7	B:p=.209	ATG	63.2	73.1	76.5
C:p=.296	ITG	69.5	68.7	73.7	C:p= .058	ITG	69.8	71.5	75.3
BC:p=.017*	CG	70.6	70.4	66.8					
Time, mins	TG	78.4	77.9	77.8					
B:p=.190	ATG	63.5	73.4	74.6					
C:p=.219	ITG	70.5	69.2	74.5					
BC:p=.011	CG	47.6	48.9	45.9	BC:p= .206	CG	69.5	71.6	69.6
$\dot{V}_E$, 1/min	TG	$^{a}59.1$	53.8	$^{a}55.8$	$\dot{V}_E/\dot{V}O_2$	TG	75.7	70.6	70.6
B:p=.228	ATG	$^{d}41.4$	52.1^{1}	53.8^{3}	B:p= .404	ATG	65.7	73.6	71.5
C:p=.143	ITG	$^{f}51.6$	53.2	$^{c}57.6^{3}$	C:p= .742	ITG	73.8	74.2	76.4

1 = Mid-Pre a = TG-CG d = ATG-TG)

2 = Post-Mid b = ATG-CG e = ITG-TG) F values significant at the .05 level

3 = Post-Pre c = ITG-CG f = ITG-ATG)

* = F value not significant at the .05 level on the basis of the Greenhouse - Geisser conservative test

Table 32 - Effect of the Four Treatments on the Selected Variables at the Pre Training Maximum Exercise Capacity Power Output in the High and Low Fit Categories Combined

Variable	Group	Pre	Mid	Post	Variable	Group	Pre	Mid	Post
BC:p=.020*	CG	123.7	126.3	121.1	BC:p= .053	CG	3.73	3.81	3.74
$\dot{V}_E$, 1/min	TG	117.1	$^{a}102.8^{1}$	$^{a}89.1^{2,3}$	$\dot{V}CO_2$, 1/min	TG	3.82	3.66	$3.45^{2,3}$
B:p=.265	ATG	123.9	114.1^{1}	$^{b}94.8^{2,3}$	B:p= .459	ATG	3.58	3.55	$^{b}3.25^{2,3}$
C:p=.000	ITG	121.3	111.2^{1}	$^{c}97.3^{2,3}$	C:p=.000	ITG	$^{f}4.12$	3.73^{1}	$3.51^{2,3}$
BC:p=.647	CG	3.11	3.10	3.04	BC:p= .178	CG	33.4	33.9	32.9
$\dot{V}O_2$, 1/min	TG	3.11	3.06	2.91^{3}	$\dot{V}_E/\dot{V}CO_2$	TG	30.9	$^{a}28.3^{1}$	$^{a}25.8^{2,3}$
B:p=.613	ATG	3.00	3.08	2.88^{2}	B:p= .011	ATG	$^{d}35.5$	$^{d}32.7^{1}$	$^{d}29.5^{2,3}$
C:p=.001	ITG	3.35	3.32	$3.06^{2,3}$	C:p= .000	ITG	$^{c,f}29.2$	$^{c,f}28.4$	$^{c}26.5^{3}$
BC:p=.014*	CG	39.8	41.4	40.4	BC;p= .011	CG	17.36	17.44	17.32
$\dot{V}_E/\dot{V}O_2$	TG	38.1	$^{a}33.9$	$^{a}30.6^{2,3}$	F_EO_2,%	TG	17.11	$^{a}16.77^{1}$	$^{a}16.20^{2,3}$
B:p=.005	ATG	$^{d}42.2$	37.6	$^{b}33.1^{2,3}$	B:p= .014	ATG	17.37	17.07^{1}	$^{b}16.48^{2,3}$
C:p=.000	ITG	$^{c,f}35.7$	$^{c,f}33.3$	$^{c}31.3^{3}$	C:p=. 000	ITG	$^{c,f}16.91$	$^{c}16.69$	$^{c}16.31^{2,3}$

1 = Mid-Pre a = TG-CG d = ATG-TG)

2 = Post-Mid b = ATG-CG e = ITG-TG) F values significant at the .05 level

3 = Post-Pre c = ITG-CG f = ITG-ATG)

* = F Value not significant at the .05 level on the basis of the Greenhouse- Geisser conservative test

CHAPTER V

DISCUSSION

SECTION A

Characteristics of the Subjects in the Fitness Categories and Treatment Groups

The mean relative maximum oxygen uptake of the high fit category was 46.4 ± 4.3 ml/kg/min (range from 42.1 to 57.6) while that for the low fit category was 36.2 ± 3.7 ml/kg/min (range from 29.2 to 42.0). The former values were slightly lower than those reported by Davis et al. (24) for thirty male subjects (mean age 22.5 yrs.) during bicycle ergometry, while the latter were slightly lower than those reported by Saltin et al. (94) for forty-two sedentary male subjects (mean age 40.5 yrs.). The mean value of the high fit category was significantly higher than that of the low fit category, but this difference could not be attributed to the lower body weight of the former category because the absolute maximum oxygen uptake was also significantly higher in this category of subjects. Since the maximum oxygen uptake is known to decrease with age (3), it is quite possible that the significantly lower age of the high fit category could have partially contributed to their higher maximum oxygen uptake.

The assignment of the subjects to the four treatment groups in each fitness category by the technique of stratified randomization, in order to equalize their relative maximum oxygen uptakes, was successful on the

first attempt. The mean maximum oxygen uptake of each treatment group in the two fitness categories was within one standard deviation of the overall mean for that fitness category. Although the groups were equated on the basis of the relative maximum oxygen uptake, no significant difference was observed between them for the absolute maximum oxygen uptake as well as the absolute oxygen uptake, relative oxygen uptake and power output at Th.1.

SECTION B

Comparison of the $\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$, F_EO_2 and F_ECO_2 Curves between Subjects

Although the gross shape of the $\dot{V}_E/\dot{V}O_2$ curve was quite similar between subjects, some variations were seen amongst them. Firstly, the initial decline to the minimum value was usually rapid in most cases but in some instances it was quite gradual. Usually, the longer the time taken to reach the minimum value, the more gradual was the decline. Secondly, the absolute value of the minimum $\dot{V}_E/\dot{V}O_2$ ratio showed a great deal of variation. The range of values obtained for the thirty-eight subjects who completed the study was between 18.3 and 32.9 (mean 24.5 ± 2.8) on the initial test. Thirdly, the power output at which this ratio reached its minimum value varied considerably between subjects - for this group it was between 360 KPM/min and 1,080 KPM/min (mean 701 ± 159) on the initial test. Finally, perhaps the most variation was observed in the subsequent incline in the $\dot{V}_E/\dot{V}O_2$ ratio after it had reached its minimum value. In some cases, this incline was very rapid while in others it was quite gradual. Occasionally, one or

two consecutive $\dot{V}_E/\dot{V}O_2$ ratios that were very close to the minimum value were observed at subsequent power outputs following which there would be a fairly rapid increase in this ratio. Usually the incline was continuous once the minimum value was reached, but in some cases it wasn't - the initial incline was followed by a slight decline and then another incline until the MEC was reached (see Figure 2).

A comparison of the curves for the $\dot{V}_E/\dot{V}CO_2$ ratio during the graded exercise test between subjects revealed differences that were similar to those reported for the $\dot{V}_E/\dot{V}O_2$ ratio. The range for the minimum $\dot{V}_E/\dot{V}CO_2$ ratios in this sample was between 20.0 and 32.1 (mean 24.9 ± 2.6), while that for the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum was between 720 KPM/min and 1,800 KPM/min (mean 1,146 ± 259) on the initial test. Although the gross shape of the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ curves was quite similar, some important differences were observed between them. Firstly, the $\dot{V}_E/\dot{V}CO_2$ ratios during the early stages of the test were usually higher than the $\dot{V}_E/\dot{V}O_2$ ratios because the volume of carbon dioxide produced at these power outputs was less than the volume of oxygen consumed at the same power output - i.e. the respiratory exchange ratio was less than unity. Secondly, the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum was always higher than that at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum. Thirdly, no specific trend was observed when the minimum values of the two ratios were compared. In some cases, the minimum $\dot{V}_E/\dot{V}O_2$ ratio was higher than the minimum $\dot{V}_E/\dot{V}CO_2$ ratio while in others the reverse was true. Fourthly, during the latter stages of the test, the $\dot{V}_E/\dot{V}CO_2$ ratios were usually lower than the $\dot{V}_E/\dot{V}O_2$ ratios at the same power output because the respiratory exchange ratio was invariably greater than unity. Consequently, the magnitude of the

increase in the $\dot{V}_E/\dot{V}CO_2$ ratio after it had reached its minimum value was considerably less that that of the $\dot{V}_E/\dot{V}O_2$ ratio, perhaps indicating that the ventilation volume was more closely geared to the carbon dioxide production rather than the oxygen consumption. Finally, the $\dot{V}_E/\dot{V}O_2$ ratio at Th.2 was always higher than that at Th.1. This point is of special significance because the $\dot{V}_E/\dot{V}O_2$ ratio is an index of the economics of ventilation. A higher $\dot{V}_E/\dot{V}O_2$ ratio implies that the oxygen cost of ventilating a unit volume of air is greater than that incurred at a lower $\dot{V}_E/\dot{V}O_2$ ratio. Since the $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 is a minimum, it indicates that the ventilation is most efficient at this power output.

The F_EO_2 curve, as illustrated in Figure 2, was quite similar to the $\dot{V}_E/\dot{V}O_2$ curve during the graded exercise test. Hence, the differences that were observed between subjects for the $\dot{V}_E/\dot{V}O_2$ curve were also observed for the F_EO_2 curve. The range of the minimum F_EO_2 values for the thirty-eight subjects who completed the study was between 14.79% and 16.36% on the initial test. The shape of the F_ECO_2 curve during the graded exercise test was different from the shapes of the three curves just discussed. The F_ECO_2 values increased with increasing power output until a maximum was reached and then decreased until the MEC was attained. Several differences were once again observed when a comparison of the F_ECO_2 curves was made between subjects. For example: (1) the rate of increase in the F_ECO_2 with increasing power output (2) the absolute value of the maximum F_ECO_2 value (3) the power output at which the maximum F_ECO_2 value was reached and (4) the rate of decrease in the F_ECO_2 after the maximum value was reached - all these

varied considerably between subjects. The range for the maximum values in this study was between 4.26% and 6.11% on the initial test.

Significance of the Relationship between the V_E/VO_2 Ratio and the F_EO_2

It should be recalled from the previous chapter that the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio and the F_EO_2 reached a minimum was identical. This occurs because the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 are mathematically related in the following manner (90):

$$\dot{V}_E/\dot{V}O_2 \propto \frac{1}{F_IO_2 - F_EO_2} \text{ ----------------------------------Eq. 15}$$

Since the value of the F_IO_2 for atmospheric air is constant at 0.2093 (13), it follows then that the $\dot{V}_E/\dot{V}O_2$ ratio will be a minimum only when the F_EO_2 is also a minimum. Keeping this relationship in mind, one can perhaps explain why the $\dot{V}_E/\dot{V}O_2$ ratio begins to increase after reaching its minimum value. The oxygen consumption, ventilation volume and F_EO_2 are mathematically related in the following manner (13):

$$\dot{V}O_2 \text{ consumed} = \dot{V}_E/100\ (\%N_2 \text{ in expired air} \times .265 - \%\ F_EO_2) \text{ --Eq.16}$$

The factor ($\%N_2$ in expired air x .265 -% F_EO_2) is known as the 'True Oxygen' factor (13). When % F_EO_2 is a minimum, the 'True Oxygen' factor becomes a maximum. This means that at this exercise intensity, the maximum amount of oxygen is consumed per unit volume of air expired - i.e. the ventilation is most efficient in terms of oxygen cost at this intensity. However, since the $\dot{V}_E/\dot{V}O_2$ ratio is a minimum when the F_EO_2 is also a minimum, it implies that the oxygen cost of ventilation is most efficient because the 'True Oxygen' factor is a maximum. At higher power outputs both the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 increase. As the latter increases, the value of the 'True Oxygen' factor decreases. Hence, in

order to maintain the linear relationship between oxygen consumption and power output which is known to exist (3) and was also observed in this study, the ventilation volume must increase by a greater proportion - i.e. a hyperventilation with respect to oxygen consumption must occur and consequently the $\dot{V}_E/\dot{V}O_2$ ratio begins to increase. This hyperventilation seems to be the mild non-linear increase in the ventilation volume that Skinner and McLellan (101) report should occur at the first of the two thresholds as a result of the accumulation of a significant amount of lactic acid in the blood.

The relationship between the $\dot{V}_E/\dot{V}O_2$ ratio and the F_EO_2 is well depicted in the scattergrams in Figures 8 and 9 for the values used in Figures 2 and 3 respectively. As can be seen, a positive linear relationship exists between the $\dot{V}_E/\dot{V}O_2$ ratio and the F_EO_2. The respective regression equations for the two scattergrams along with their standard errors of estimate and regression coefficients are:

$Y = 11.95X - 168.7$; SEE $= 0.77$; $r = 0.993$ ----------------- Eq. 17

$Y = 8.66X - 111.3$; SEE $= 0.65$; $r = 0.989$ ------------------ Eq. 18

where Y = predicted $\dot{V}_E/\dot{V}O_2$

X = % F_EO_2

SEE = standard error of estimate

r = correlation coefficient between F_EO_2 and $\dot{V}_E/\dot{V}O_2$

Significance of the Relationship between the $\dot{V}_E/\dot{V}CO_2$ Ratio and the F_ECO_2

As mentioned earlier, the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum and the F_ECO_2 reached a maximum during the graded exercise test was identical. If an analogy similar to the one reported

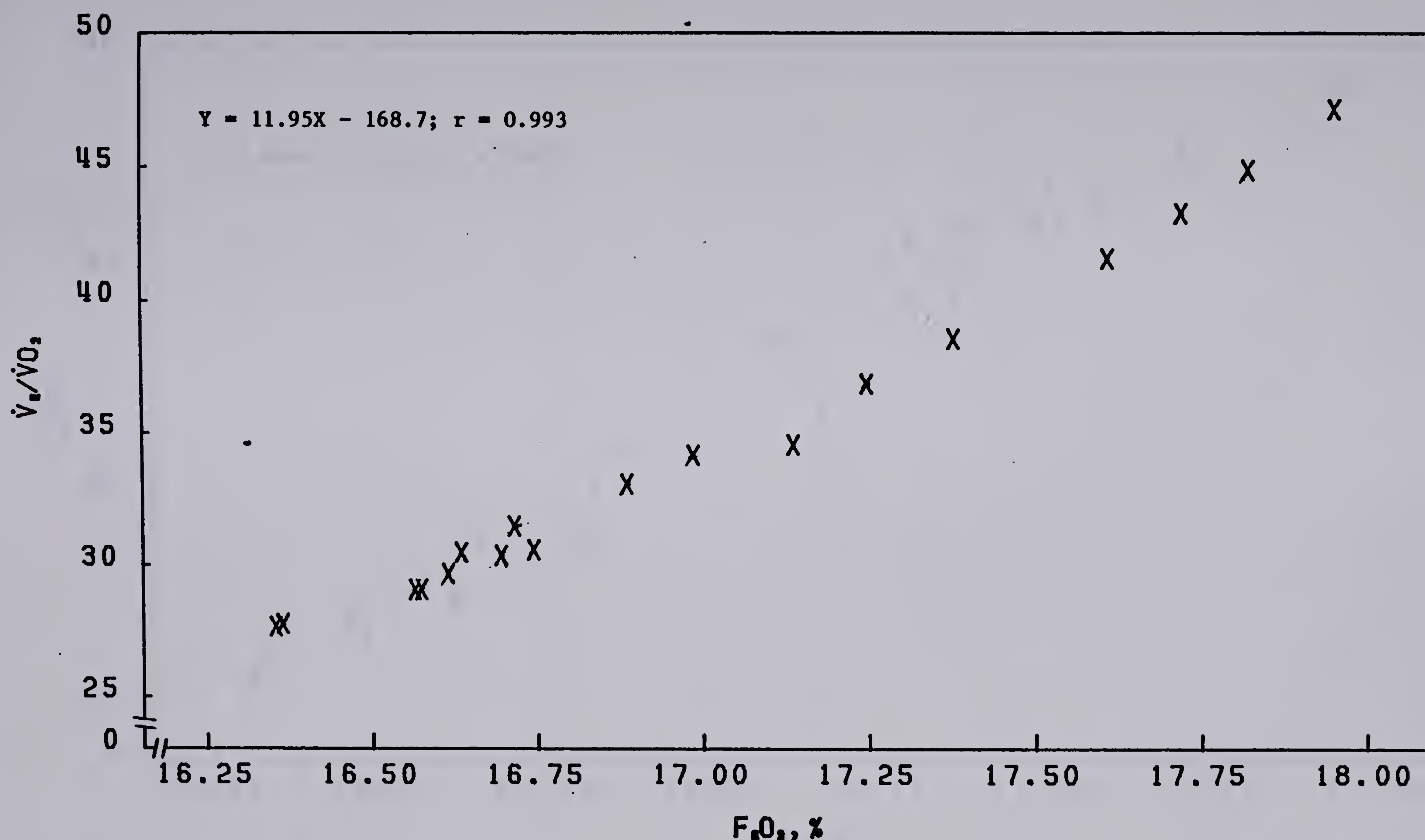


Figure 8 - Relationship between the Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for One Subject

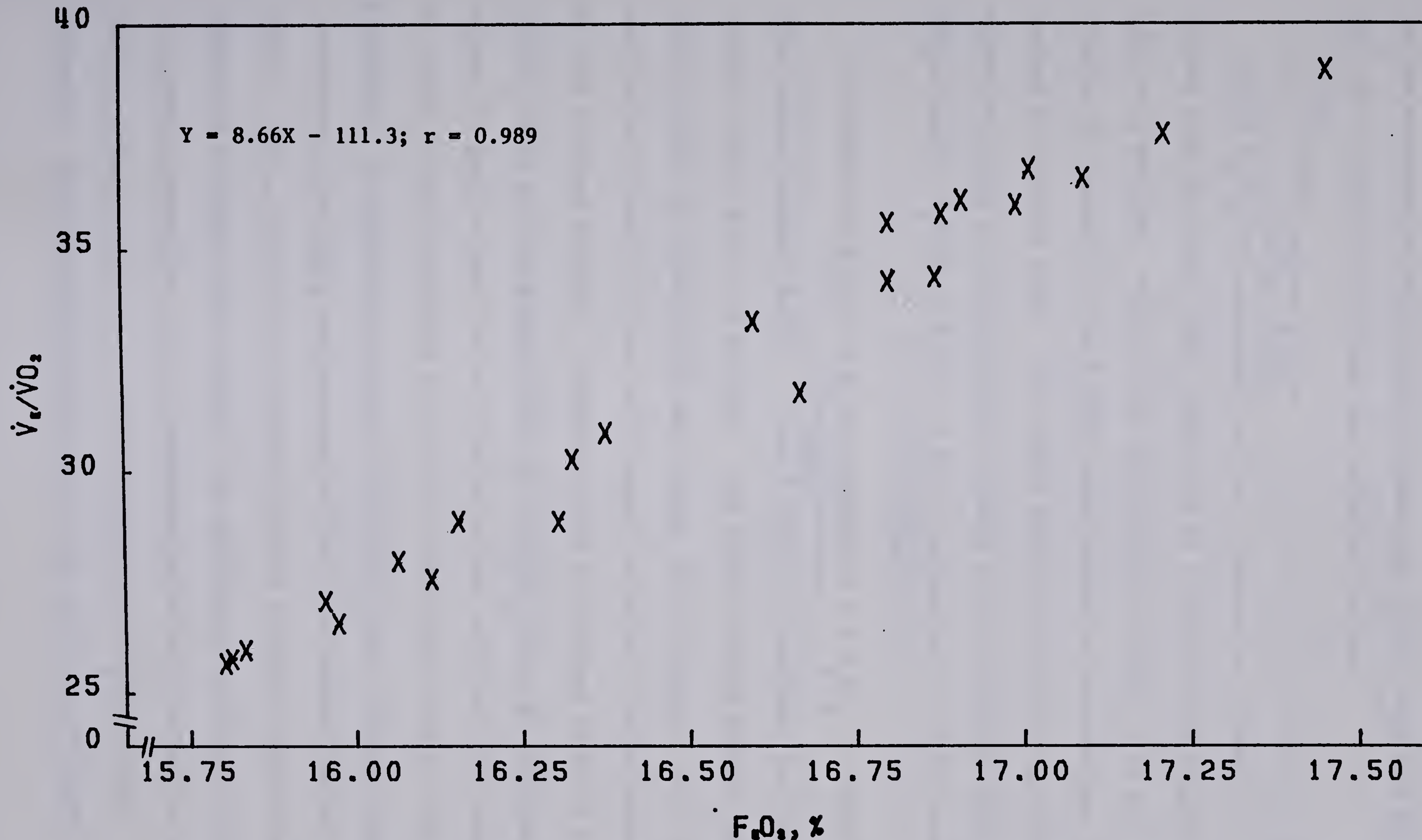


Figure 9 - Relationship between the Pre Training $\dot{V}_E/\dot{V}O_2$ Ratio and F_EO_2 during the Graded Exercise Test for the Sample of Thirty Eight Subjects

for the mathematical relationship between the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 (Eq. 15) is drawn up for these two variables, we get:

$$\dot{V}_E/\dot{V}CO_2 \propto \frac{1}{F_ECO_2 - F_ICO_2} \qquad \text{----------------------------------Eq. 19}$$

Since F_ECO_2 for atmospheric air is a constant at 0.0003 (13), it follows then that the $\dot{V}_E/\dot{V}CO_2$ ratio will be a minimum only when the F_ECO_2 is a maximum. Bearing this relationship in mind, it is now possible to explain why the $\dot{V}_E/\dot{V}CO_2$ ratio begins to increase once it has reached its minimum value. The carbon dioxide production, ventilation volume and F_ECO_2 are mathematically related in the following manner (13):

$$\dot{V}CO_2\text{produced} = \dot{V}_E/100\ (\%\ F_ECO_2 - \frac{\%\ N_2 \text{ in expired air} \times \%\ F_ECO_2}{79.04})\text{---Eq. 20}$$

The factor $(\%\ F_ECO_2 - \frac{\%\ N_2 \text{ in expired air} \times \%\ F_ECO_2}{79.04})$ is known as the 'True Carbon Dioxide' factor. When $\%\ F_ECO_2$ is a maximum, the 'True Carbon Dioxide' factor also is a maximum. This means that the maximum amount of carbon dioxide is produced per unit volume of air expired - i.e. the ventilation is most efficient with respect to carbon dioxide production at this exercise intensity. However, since the minimum value of the $\dot{V}_E/\dot{V}CO_2$ ratio and the maximum value of the F_ECO_2 occur at the same power output, it implies that the ventilation is most efficient with respect to carbon dioxide production because the 'True Carbon Dioxide' factor is a maximum. At higher power outputs the $\dot{V}_E/\dot{V}CO_2$ ratio increases despite a decrease in the F_ECO_2 and the value of the 'True Carbon Dioxide' factor. Hence, in order to compensate for the increased carbon dioxide production at higher power outputs, the ventilation volume must increase by a greater proportion - i.e. a hyperventilation with respect to carbon dioxide production must occur and consequently the $\dot{V}_E/\dot{V}CO_2$ ratio increases. This hyperventilation seems to be the large non-linear

increase in the ventilation volume that Skinner and McLellan (101) report should occur at the second threshold as a result of the large increases in the blood lactate concentration. Reinhard et al. (90) report that this appears to be the exercise intensity at which the capillary pH begins to decrease significantly - a humoral factor that has been reported to stimulate the respiratory centre during exercise (106).

The relationship between the $\dot{V}_E/\dot{V}CO_2$ ratio and the F_ECO_2 is illustrated in the scattergrams in Figures 10 and 11 for the values used in Figures 4 and 5 respectively. In this case, an inverse relationship exists between the two variables. The respective regression equations for the two scattergrams along with their standard errors of estimate and regression coefficients are:

$Y = -9.1X + 69.9$; SEE = 0.10; $r = -0.999$ ------------------ Eq. 21

$Y = -7.2X + 62.9$; SEE = 0.50; $r = -0.992$ ------------------ Eq. 22

where Y = predicted $\dot{V}_E/\dot{V}CO_2$

X = % F_ECO_2

SEE = standard error of estimate

r = correlation coefficient between F_ECO_2 and $\dot{V}_E/\dot{V}CO_2$

Increases in the Ventilation Volume at Threshold One and Threshold Two

When describing the curve for the ventilation volume during the graded exercise test in the previous chapter, it was mentioned that considerable difficulty was experienced in identifying non-linear increases in the ventilation volume that were supposed to occur at the two thresholds. Several other investigators (24, 104, 123) have experienced problems in identifying such increases in different

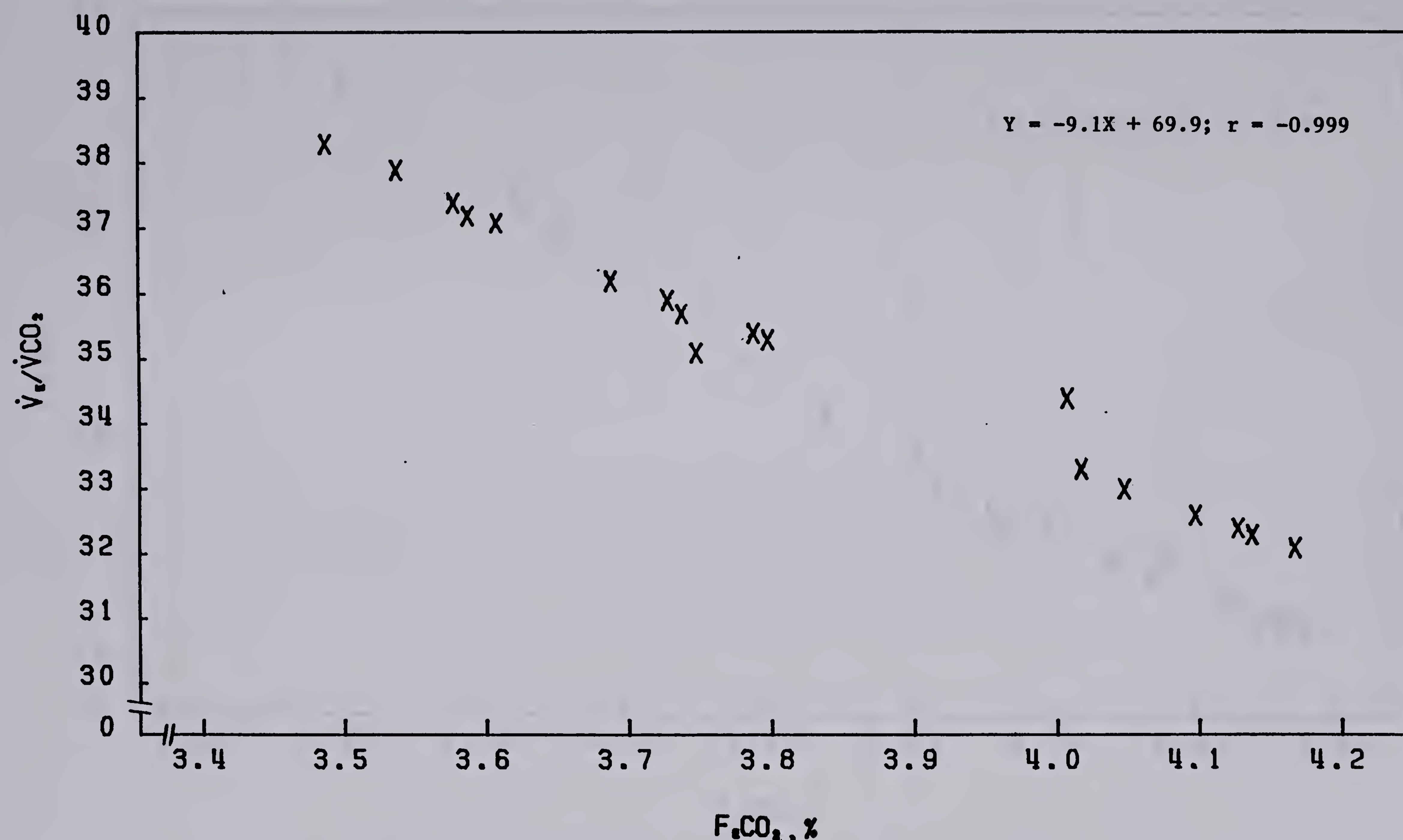
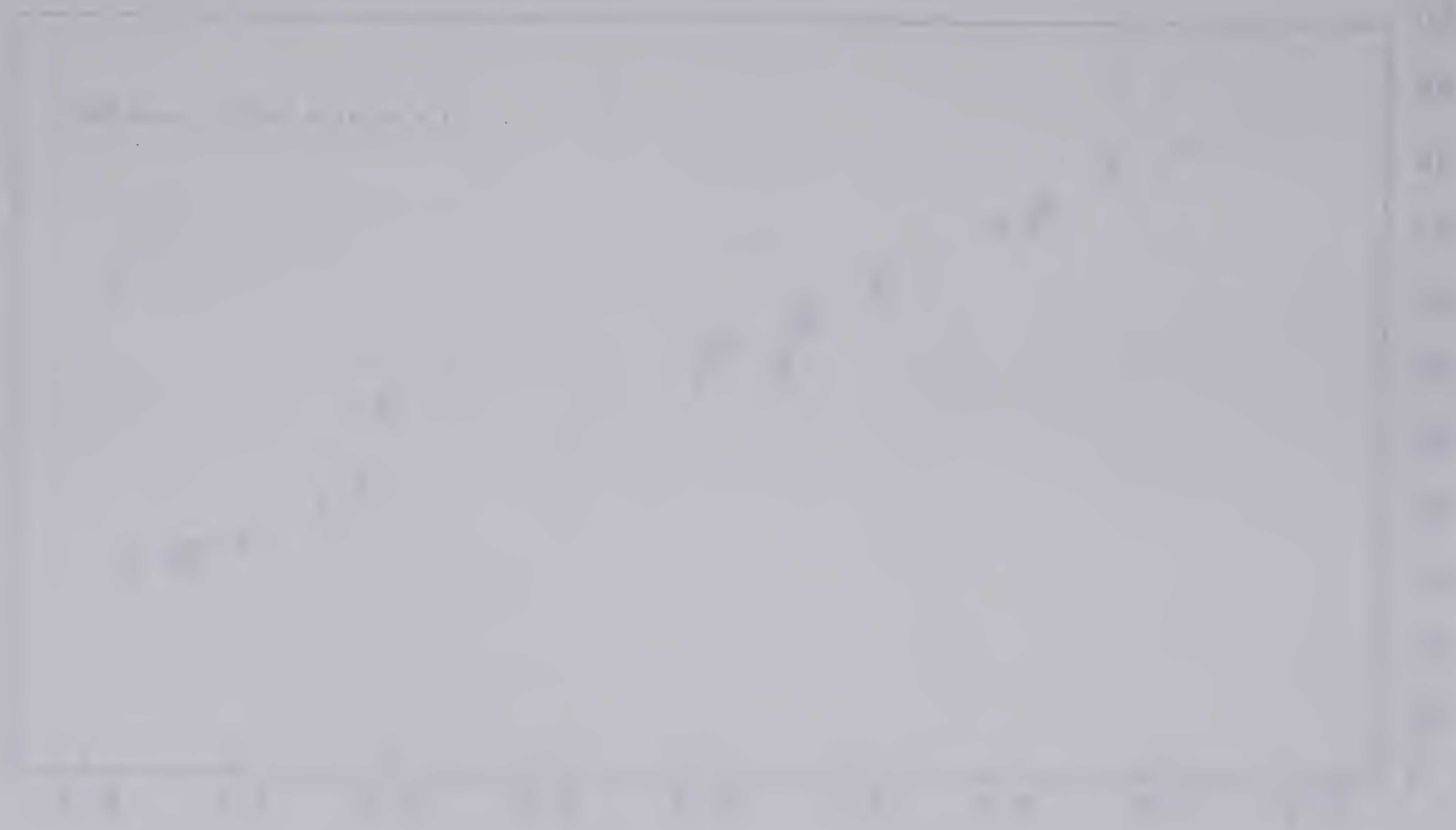


Figure 10 – Relationship between the Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for One Subject



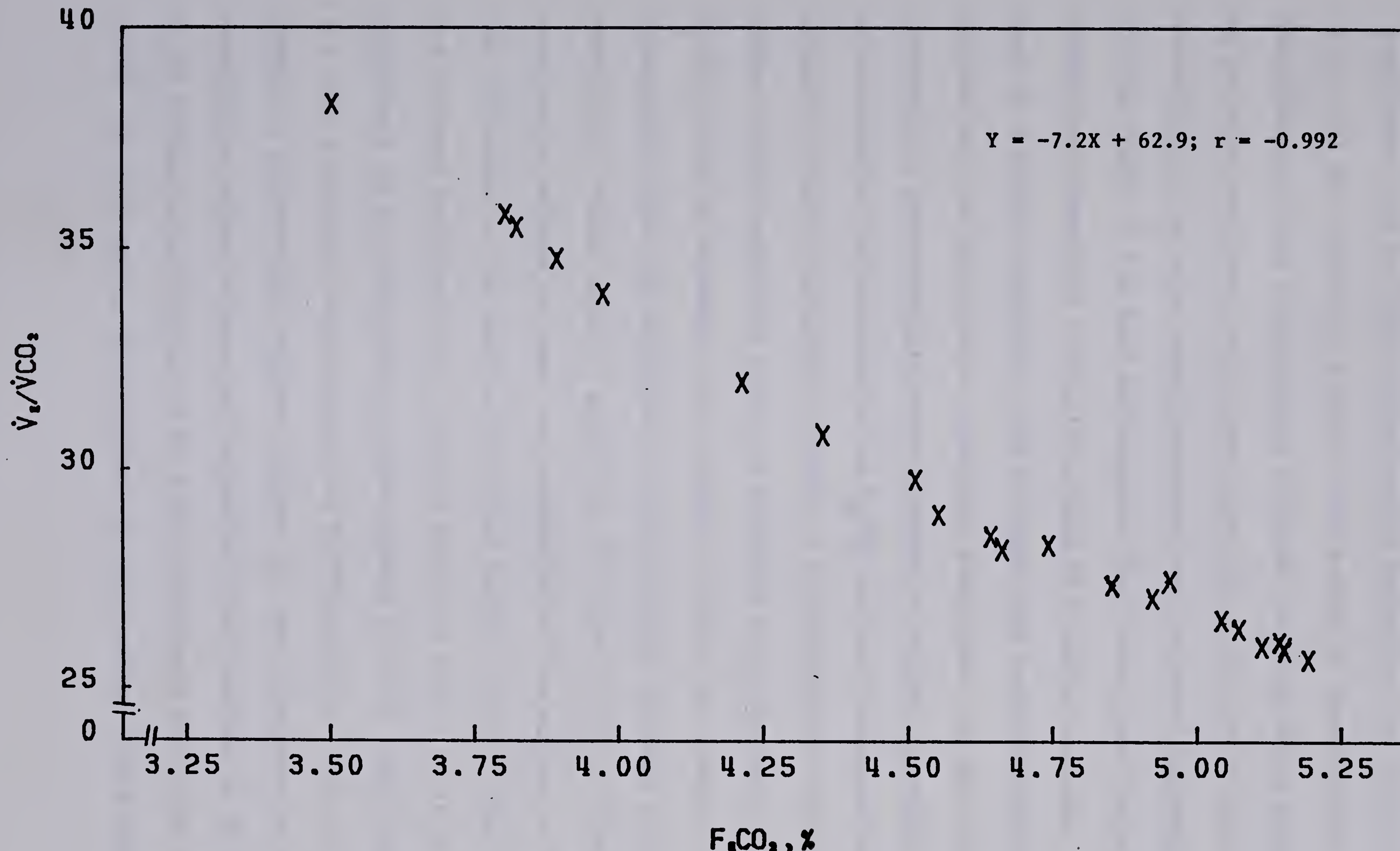
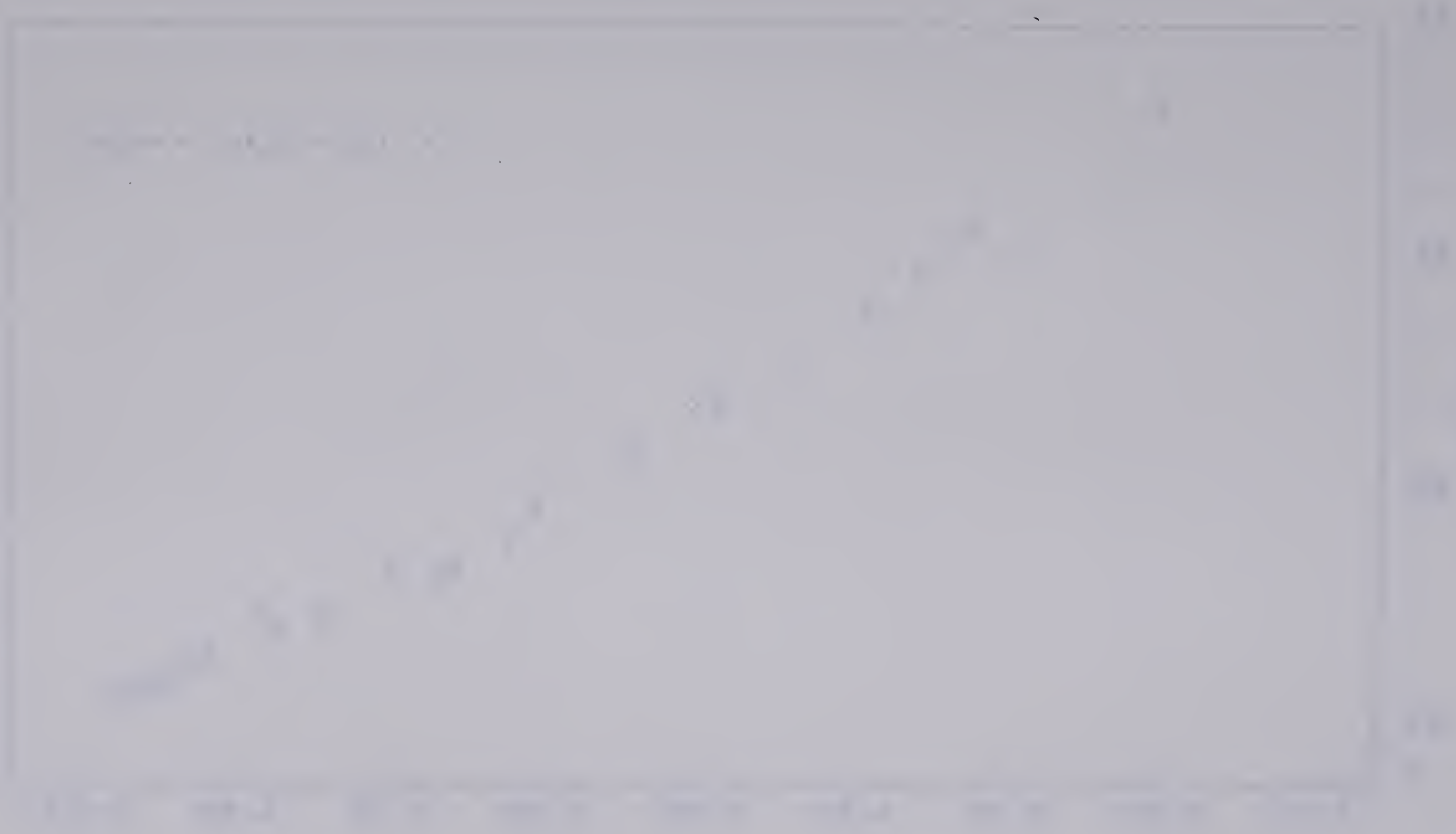


Figure 11 – Relationship between the Pre Training $\dot{V}_E/\dot{V}CO_2$ Ratio and F_ECO_2 during the Graded Exercise Test for the Sample of Thirty Eight Subjects



variables when attempting to detect the AT. This is because the term 'non-linear' has not been mathematically defined by the researchers (113, 116) who originally proposed this method of investigation. Nevertheless, these investigators selected the point which appeared to be the most non-linear and in some cases (24, 123) have admitted the possibility of an error being committed (see Review of Literature). In this study, it has been demonstrated that there appear to be two ventilatory thresholds during the course of a graded exercise test on a bicycle ergometer, both of which have been mathematically defined and can therefore be accurately identified. At the first threshold, a hyperventilation with respect to oxygen consumption occurs as evidenced by the increase in the $\dot{V}_E/\dot{V}O_2$ ratio at subsequent power outputs, while at the second threshold, a hyperventilation with respect to carbon dioxide production occurs as evidenced by the increase in the $\dot{V}_E/\dot{V}CO_2$ ratio at subsequent power outputs. Skinner and McLellan (101) hypothesized that the magnitude of the non-linear increase in the ventilation volume would be greater at Th.2 than at Th.1. Examining the ventilation volumes at these two thresholds for the subject in Figure 6, the difference in the ventilation volume between the Th.1 time interval and the next successive time interval was 3,410 ml/min or 16.7%. The difference in the ventilation volume between the Th.2 time interval and the next successive time interval was 9,509 ml/min or 23.8%. For the sample of thirty-eight subjects (Figure 7), the difference in the ventilation volume between two successive time intervals at Th.1 was 4,723 ml/min or 12.6% while at Th.2 this difference was 10,162 ml/min or 14.7%. In both cases, the magnitude of the increase in the ventilation

volume at Th.2 was greater than that at Th.1 - in agreement with Skinner and McLellan's (101) hypothesis.

Values of the Selected Variables at Thresholds One and Two

The means, standard deviations and ranges of the selected variables at Th.1 and Th.2 obtained on the initial test for the thirty-eight subjects who completed this study are given in Table 33. The value of each of these variables expressed as a percentage of the corresponding variable at the MEC is also given. It can be seen from this table that for each of the variables at the two thresholds, the range was quite wide. However, when the individual values were examined (Tables 35-62, Appendix C), most of them were within one standard deviation of the mean.

(1) Threshold One

In this study, the subjects reached Th.1 at a mean power output of 701 ± 159 KPM/min or 41.5% of the power output at the MEC on the initial test. The values ranged between 360 KPM/min to 1,080 KPM/min. Reinhard et al. (90) report the mean power output at the AT (Th.1) to be 474.0 ± 145 KPM/min or 35.4% of the power output at the MEC in thirty-six male subjects between twenty and thirty-nine years of age. The slightly higher values observed in this study are probably due to the different testing protocols used in the two studies. In this study, the power output was increased by 180 KPM/min every minute, whereas in the study cited the power output was increased by 100 KPM/min every minute. These researchers have not directly reported the oxygen consumption at this threshold, but by observing their scattergram (Figure 3, page 39) for the subjects between twenty and thirty-nine

Table 33 - Means, Standard Deviations and Ranges of Selected Variables at Threshold One and Threshold Two observed in this Study

Variable	THRESHOLD ONE Mean	SD	Min	Max	THRESHOLD TWO Mean	SD	Min	Max
Power Output KPM/min	701	159	360	1080	1146	259	720	1800
Time mins	4.6	0.9	2.5	7.0	7.1	1.5	4.5	11.0
$\dot{V}_E$ 1/min	34.3	7.5	20.5	56.1	59.1	15.1	35.3	98.0
$\dot{V}O_2$ 1/min	1.41	0.30	0.74	2.29	2.16	0.51	1.27	3.57
$\dot{V}O_2$ ml/kg/min	18.6	4.1	10.0	30.0	28.5	6.9	17.0	42.7
$\dot{V}_E/\dot{V}O_2$	24.5	8.1	18.3	32.9	27.4	9.8	22.3	36.6
Power Output %	41.5	8.1	25.0	55.6	67.7	11.7	44.4	90.9
Time %	45.7	6.9	27.8	58.3	70.6	11.3	47.4	91.7
$\dot{V}_E$ %	28.1	6.4	17.4	44.6	48.5	12.4	25.0	71.1
$\dot{V}O_2$ %	45.1	6.9	29.6	60.3	68.8	11.0	46.4	85.5
$\dot{V}_E/\dot{V}O_2$ %	62.1	7.4	45.8	76.8	69.8	9.3	49.0	84.2

years of age, it appears that their absolute values are lower than those reported in this study. For the thirty-eight subjects in this study, the mean and standard deviation of the absolute oxygen uptake at Th.1 was 1.41 l/min $\pm$ 0.30 l/min, the values ranging between 0.74 l/min to 2.29 l/min. The mean and standard deviation of the relative values were 18.6 ml/kg/min $\pm$ 4.1 ml/kg/min, the values ranging between 10.0 ml/kg/min and 30.0 ml/kg/min. The absolute values illustrated in Reinhard et al. (90) ranged between approximately 0.80 l/min and 1.50 l/min, with most of the values ranging between 0.80 l/min and 1.20 l/min. The higher oxygen consumption observed in this study was most probably a consequence of the higher power output at which this threshold occurred.

(2) Threshold Two

A comparison between the mean power output at Th.2 observed in this study and at the TDMA observed by Reinhard et al. (90) reveals that the value obtained in this study, 1,146 $\pm$ 259 KPM/min, was higher than that reported by the researchers cited, 911 $\pm$ 204 KPM/min. However, when these values were expressed as a percentage of the power output at the MEC, both studies reported similar values: 67.7% vs. 68.0%. The oxygen consumption at Th.2 observed in this study seems to be higher than the values plotted by Reinhard et al. (90) in their scattergram (Figure 3, page 39). The range obtained in this study was between 1.27 l/min and 3.57 l/min, with a mean and standard deviation of 2.16 $\pm$ 0.51 l/min respectively. The range observed in the study cited was approximately between 1.30 l/min and 2.50 l/min, with a majority of the values ranging between 1.30 l/min and 2.00 l/min. The reasons for the slightly higher values of the power output and oxygen consumption observed in

this study are most probably similar to those given for the higher values observed at Th.1.

The results in Table 33 revealed some interesting information when the ventilation volume and oxygen consumption at the two thresholds were expressed as percentages of the corresponding variables at the MEC. At Th.1, the oxygen consumption was 45.1 ± 6.9% of the maximum oxygen uptake whereas the ventilation volume was only 28.1 ± 6.4% of the maximum ventilation volume. At Th.2, the oxygen consumption was 68.8 ± 11.0% of the maximum oxygen uptake while the ventilation volume was 48.5 ± 12.4% of the maximum ventilation volume. At both these thresholds, the oxygen consumption constituted a larger proportion of the maximum value than the ventilation volume indicating that at power outputs above these two thresholds, a hyperventilation with respect to oxygen consumption occurred until the MEC was attained. When the mean values of the power output, time, ventilation volume, oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 and Th.2 were compared, it was observed that the values at Th.2 were 1.63, 1.54, 1.72, 1.53 and 1.12 times greater than those at Th.1 respectively.

SECTION C

Inter-relationship between the Selected Variables at:

(1) The Maximum Exercise Capacity

In this study, the correlation between the power output and time at the MEC was significant on all three test trials in all three categories. Also, the correlation between the power output and

absolute oxygen consumption was significant in each case, except on the post test in the low fit category. These results are in agreement with the report (3) that a higher absolute maximum oxygen uptake is usually achieved at a higher power output and after a longer period of time. The relative maximum oxygen uptake was significantly related to the absolute value on all three tests only when the high and low fit categories were combined. When these two categories were separated, the relationship between these two variables was not consistently significant on the three test trials. These results indicate that in a heterogeneous sample, individuals with high absolute maximum oxygen uptakes generally have high relative values for this variable, but when the sample is homogeneous, this is not necessarily true - other factors such as body weight play an important role.

The maximum ventilation volume was significantly related to the absolute maximum oxygen uptake on all three test trials in all three categories except on the mid test in the low fit category. According to Equation 16 on page 109, the ventilation volume and oxygen consumption are related in the following manner:

$$\dot{V}O_2 \text{ consumed} = \dot{V}_E/100 \ (\% \ N_2 \text{ in expired air} \times .265 - \% \ F_EO_2)$$

It can be seen from this equation that for a given F_EO_2, an increase in the ventilation volume will result in an increase in the volume of oxygen consumed. However, it was shown that at exercise intensities above Th.1, the F_EO_2 was not constant but was continuously increasing. Despite this, a significant relationship was observed between the ventilation volume and absolute maximum oxygen uptake, an observation which is in agreement with the results reported by Astrand and Rodahl (3). These authors state that although a positive correlation

does exist between the maximum ventilation volume and the maximum oxygen uptake, the former is not a well defined parameter since a well motivated individual can continue exercising anaerobically at power outputs above that at which the maximum oxygen uptake is reached with a large increase in the ventilation volume. This phenomenon was observed in a few subjects in this study.

The correlation between the power output and the $\dot{V}_E/\dot{V}O_2$ ratio at the MEC was insignificant in all cases, except on the post test in the high fit and combined categories when these two variables were negatively related to each other. In the remaining seven cases, the correlation between these two variables was negative five times and positive only twice indicating that individuals who had higher power outputs at the MEC tended to have lower $\dot{V}_E/\dot{V}O_2$ ratios.

Because of the mathematical relationship between the ventilation volume and the oxygen consumption in the $\dot{V}_E/\dot{V}O_2$ ratio, one would expect a significant positive relationship between the ventilation volume and the $\dot{V}_E/\dot{V}O_2$ ratio and a significant negative relationship between the absolute oxygen consumption and the $\dot{V}_E/\dot{V}O_2$ ratio. The former relationship turned out as expected on all three test trials in all three categories. However, the latter relationship proved to be significant only on the mid and post tests when the high and low fit categories were combined. Although the correlations in the other cases were insignificant, they were negative in all cases except one. These results indicate that there was a tendency for the oxygen cost of ventilation at the MEC ($\dot{V}_E/\dot{V}O_2$ max) to increase with the maximum ventilation volume and to decrease with the maximum oxygen uptake.

(2) Threshold One

The inter-correlations between the power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption were reported to be significant in all cases, except on the post test in the low fit category when the ventilation volume was not significantly related to the power output, time or relative oxygen consumption. These results imply that in most cases, especially in a heterogeneous sample, individuals who reach Th.1 at higher power outputs also have higher ventilation volumes, absolute oxygen consumptions and relative oxygen consumptions at this threshold, besides taking a longer time to reach it. These results support the well known fact that the power output, ventilation volume and oxygen consumption are linearly related to each other at submaximal intensities of exercise (3).

A significant inverse relationship between the power output and $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 was observed only on the pre test in the low fit category. In the remaining eight cases, the correlation between these two variables was negative in four instances and positive in four. Hence it appears that there was no real tendency for individuals who reached Th.1 at a higher power output to have lower $\dot{V}_E/\dot{V}O_2$ ratios. The correlation between the ventilation volume and the $\dot{V}_E/\dot{V}O_2$ ratio was significant in all three categories only on the post test. On the mid test, this relationship was significant in the high fit and combined categories and was approaching significance in the low fit category. On the pre test, the correlation was insignificant in all three categories. These results indicate that there was a tendency for the $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 to increase with the ventilation volume. The correlation between the absolute oxygen consumption and the $\dot{V}_E/\dot{V}O_2$ ratio was insignificant

in all nine cases. Six of these correlations were negative and three were positive, thereby making it difficult to observe any trend between these two variables.

(3) Threshold Two

The inter-correlations between the power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption at Th.2 were significant on all three test trials in all three categories. In other words, the individuals who reached Th.2 at a higher power output and therefore took more time, also had a higher ventilation volume, absolute and relative oxygen consumption at this threshold. These results once again support the fact that a linear relationship exists between the power output, oxygen consumption and ventilation volume at submaximal exercise intensities (3).

The correlations between the $\dot{V}_E/\dot{V}O_2$ ratio and: (1) the power output and (2) the absolute oxygen consumption were similar to those reported at the MEC. The relationship between these variables was insignificant in most cases, indicating that individuals who reached Th.2 at higher power outputs and oxygen consumptions did not necessarily have higher $\dot{V}_E/\dot{V}O_2$ ratios. The correlation between the $\dot{V}_E/\dot{V}O_2$ ratio and the ventilation volume was significant in all cases except in the high fit category on the pre test. This implies that as the ventilation volume increases, the $\dot{V}_E/\dot{V}O_2$ ratio also increases thereby increasing the oxygen cost of ventilating this volume of air at this threshold.

Inter-relationship between the Maximum Exercise Capacity, Threshold One and Threshold Two for the Selected Variables

The correlations between the MEC and Th.1 for the power output,

time, ventilation volume, absolute oxygen consumption, relative oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio were not consistently significant on all three test trials in all three categories. However, in the combined category the correlation between these two reference points for the absolute and relative oxygen consumptions was significant on all three test trials, indicating that individuals who had higher maximum oxygen uptakes also seemed to have higher oxygen consumptions at Th.1. These results are in agreement with the correlations between the oxygen uptake at the AT and the maximum oxygen uptake reported in Table 2. Another interesting observation was that the $\dot{V}_E/\dot{V}O_2$ ratio at the MEC (V_E/VO_2 max) was significantly related to the V_E/VO_2 ratio at Th. 1 (V_E/VO_2 min) on all three test trials in the combined category. In other words, there was a tendency for the individuals with a higher oxygen cost of ventilation at the maximum oxygen uptake to have a higher oxygen cost of ventilation at the exercise intensity at which this cost was the least.

The correlations between the MEC and Th.2 for the power output, absolute oxygen consumption and relative oxygen consumption were significant on all three test trials in all three categories. The correlations between these two reference points for the ventilation volume and $\dot{V}_E/\dot{V}O_2$ ratio were significant on all three test trials only in the combined category. The most significant of all these correlations was that between the absolute oxygen consumption at Th.2 and the MEC. The regression equations computed for the combined category for predicting the oxygen consumption at this threshold from the maximum oxygen consumption on the pre, mid and post tests respectively were:

$$Y = 0.74X - 171.9;\ SEE = 357.4;\ r = 0.733 \quad \text{------------------} \quad \text{Eq. 23}$$

$$Y = 0.81X - 272.2;\ SEE = 300.7;\ r = 0.789 \quad \text{------------------} \quad \text{Eq. 24}$$

$$Y = 0.86X - 340.2;\ SEE = 334.2;\ r = 0.686 \quad \text{------------------} \quad \text{Eq. 25}$$

where Y = predicted absolute oxygen consumption at Th.2

X = absolute maximum oxygen uptake

SEE = standard error of estimate

r = correlation coefficient between the absolute oxygen consumption at Th.2 and the absolute maximum oxygen consumption.

The correlations between Th.1 and Th.2 for the six selected variables were significant on all three test trials only when the high and low fit categories were combined. These results indicate that in a heterogeneous sample of subjects, individuals who have higher values for each of these variables at Th.1 also seem to have higher values for the corresponding variables at Th.2.

To summarize the above discussion, it can be said that in a heterogeneous sample of subjects, there seems to be a significant inter-relationship between the three reference points namely: (1) Th.1 (2) Th.2 and (3) the MEC for the following six variables namely: (1) power output (2) time (3) ventilation volume (4) absolute oxygen consumption (5) relative oxygen consumption and (6) $\dot{V}_E/\dot{V}O_2$ ratio. When the sample is relatively homogeneous, the relationship between Th.2 and the MEC remains significant only for the power output, time, absolute oxygen consumption and relative oxygen consumption. Moreover, the values of the correlations between Th.2 and the MEC for the selected variables were in most cases higher than those between Th.1 and the MEC.

These observations indicate that for the variables under consideration, Th.2 seems to be more closely related to the MEC than Th.1.

SECTION D

Comparison between the High and Low Fit Categories for the Selected Variables at:

1) The Maximum Exercise Capacity

In this study, the subjects were blocked into two fitness categories on the basis of their relative maximum oxygen uptakes. The upper half of the sample was arbitrarily classified as the high fit category while the lower half was classified as the low fit category. The results reported in Table 22 indicate that both the relative as well as the absolute maximum oxygen uptakes were significantly higher in the high fit category when compared to the low fit category on the pre, mid and post tests. However, the power output, time and ventilation volume at the MEC were not significantly different between the two fitness categories, although the mean values of all three variables were consistently higher in the high fit category on all three test trials. The fact that the high fit category had a significantly higher maximum oxygen uptake without a significantly higher maximum ventilation volume tends to support the belief (75) that the maximum ventilation volume is not a factor that limits the maximum oxygen uptake. Comparisons between the two fitness categories for the $\dot{V}_E/\dot{V}O_2$ ratio revealed that the values of this ratio were significantly lower by approximately 10.9%

and 9.7% in the high fit category on the pre and mid tests respectively, while the post test difference of 7.8% between the two fitness categories was not significant. The lower $\dot{V}_E/\dot{V}O_2$ ratios observed at the MEC in the high fit category could be attributed primarily to their higher absolute maximum oxygen uptakes rather than their maximum ventilation volumes. These results are in agreement with those reported by Martin et al. (72) who observed a significantly lower maximum $\dot{V}_E/\dot{V}O_2$ ratio in endurance athletes compared to non-athletes and seem to corroborate the earlier report (see Section C) that there was a tendency for the maximum $\dot{V}_E/\dot{V}O_2$ ratio to be negatively related to the maximum oxygen uptake.

2) Threshold One

The comparisons between the two fitness categories for the selected variables at Th.1 (Table 23) were slightly different from those reported at the MEC. The mean values of the power output, time and ventilation volume were slightly higher in the high fit category on all three test trials as was the case at the MEC, but the only comparisons that proved to be significantly different were: (1) the power output on the post test which was 23.3% higher in the high category and (2) the time on the pre and mid tests which was higher by 20.5% and 16.3% respectively in the same category of subjects. The absolute oxygen uptake at this threshold was also significantly higher in the high fit category by 25.1% and 21.6% on the pre and mid tests respectively, but the post test difference of 15.0% was not significantly different between the two fitness categories. The relative oxygen uptake at this threshold, like the relative maximum oxygen uptake, was significantly higher by 30.8%, 26.9% and 20.2% in the high fit category on the three respective

test trials. The higher mean values of the time, ventilation volume, absolute oxygen uptake and relative oxygen uptake observed at Th.1 in the high fit category was probably a consequence of their higher mean power output observed on the three test trials. The $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 ($\dot{V}_E/\dot{V}O_2$ minimum) was not significantly different between the two fitness categories on any of the tests, implying that the optimal ventilatory efficiency (in terms of oxygen consumption) was quite similar in the sample of subjects tested.

3) Threshold Two

The comparisons between the fitness categories for the selected variables at Th.2 (Table 24) were quite similar to those reported for Th.1. As was the case at the MEC and Th.1, the mean values of the power output, time and ventilation volume were slightly higher in the high fit category on all three test trials, but the only comparisons that were significantly different were: (1) the power output on the mid test which was higher by 16.9% and (2) the time on the mid and post tests which was higher by 14.7% and 13.4% respectively. As was the case at the MEC, both the absolute and relative oxygen uptakes at this threshold were significantly higher in the high fit category on all three test trials. The absolute oxygen uptake was higher by 26.5%, 22.2% and 18.5% on the pre, mid and post tests respectively, while the relative maximum oxygen uptake was higher by 33.6%, 28.5% and 24.9% on the three respective tests. Once again, the $\dot{V}_E/\dot{V}O_2$ ratio was lower in the high fit category by 6.7%, 7.0% and 3.0% on the pre, mid and post tests respectively, but none of these differences proved to be statistically significant.

Reinhard et al. (90) reported that the power output at the AT

(Th.1) was approximately one-third the MEC while that at the TDMA (Th.2) was approximately two-thirds the MEC. Skinner and McLellan (101) suggested that the first threshold (Th.1) would occur between 40% and 60% of the maximum oxygen uptake, while the second threshold (Th.2) would occur between 65% and 90% of the maximum oxygen uptake. The results reported in Tables 25 and 26, which express the values of the selected variables at the two thresholds as a percentage of the corresponding variables at the MEC for the three test trials, seem to be in agreement with the values reported by the researchers cited. Moreover, these values do not seem to be influenced by the fitness level of the subjects, because no significant differences were observed between the two fitness categories for any of these values at the two thresholds.

Generally speaking, comparisons between the two fitness categories for the six variables at the MEC, Th.1 and Th.2 revealed that similar trends were observed at all three reference points. The variables that had higher or lower values (not necessarily significant) at the MEC in a particular category of subjects also had higher or lower values at Th.1 and Th.2 in the same category of subjects. In other words, the five variables, namely, power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption which were higher in the high fit category at the MEC were also higher in this fitness category at Th.1 and Th.2. The $\dot{V}_E/\dot{V}O_2$ ratio which was lower in the high fit category at the MEC was also lower in this fitness category at Th.1 and Th.2. Special mention should be made of the fact that the relative oxygen uptake was significantly higher in the high fit category at all three reference points while the ventilation volume was not

significantly different between the two fitness categories at any of these reference points.

Comments on the Training Program

According to the position statement published by the American College of Sports Medicine (1), the minimum threshold for bringing about a significant increase in the maximum oxygen uptake in healthy adults is a training intensity which corresponds to approximately fifty percent of the maximum oxygen uptake and is carried out for fifteen continuous minutes at least three times a week. The training frequency, intensity and duration of the three experimental groups utilized in this study were described in Chapter III. Although all three training groups did the same amount of work, the relative stress was quite different in each group.

In the TG, the training intensity was monitored so that it was approximately ten percent above the oxygen consumption at Th.1. For the high fit category this was approximately fifty-three percent of the maximum oxygen uptake whereas in the low fit category this corresponded to approximately fifty-seven percent of the maximum oxygen uptake. In the ATG, the training intensity was monitored so that it corresponded to an oxygen consumption that was approximately fifty percent between that at Th.1 and the maximum oxygen uptake. For the high and low fit categories, this corresponded to approximately seventy-three and seventy-two percent of the maximum oxygen uptakes respectively. It is interesting to note that the training intensity for the TG in the two fitness categories was approximately twenty percent below the oxygen consumption at Th.2 expressed as a percentage of the maximum oxygen

uptake, while that for the ATG in the two fitness categories was approximately ten percent above the oxygen consumption at Th.2 expressed as a percentage of the maximum oxygen uptake. In the ITG, the training intensity corresponded to one-hundred percent of the maximum oxygen uptake in both fitness categories with work:rest intervals of one minute each. The training intensities for all three experimental groups in both the fitness categories were above the minimum threshold recommended by the American College of Sports Medicine (1) for improving the maximum oxygen uptake.

The subjects in the TG experienced no physical difficulty in completing the thirty minute training sessions. Their main difficulty seemed to be boredom because many of them felt that the task was not challenging enough since the training intensity was quite light. The subjects in the ATG and ITG, however, did experience physical difficulties in completing the initial training sessions. In the former group, some of the subjects were initially unable to complete the training session in one attempt. In these instances the subjects were given a second attempt after sufficient rest, usually five minutes, so that they completed the specified amount of work. In the latter group, some of the subjects were initially unable to complete the entire training session with a one minute rest interval interspersed between one minute work intervals. In these instances, the last three or four work repetitions were interspersed with one and a half minutes of rest. However, as the training progressed, all the subjects adapted very well and were able to accomplish the goals that were prescribed for them.

Effect of the Four Treatments on the Selected Variables at:

(1) The Maximum Exercise Capacity

The power output at the MEC increased significantly in all three training groups while the CG showed no significant change in this variable. As a consequence of this increased power output, the time, ventilation volume, absolute oxygen consumption and relative oxygen consumption at the MEC also increased significantly in all three training groups. In order to determine which training intensity was the most effective, the subjects in the two fitness categories were assigned to their treatment groups in a manner such that their pre training relative maximum oxygen uptakes were not significantly different from each other. By comparing the values between the treatment groups at the end of the training, one could indicate which treatment was the most effective. Table 27 showed that despite pooling the values of the high and low fit categories for each treatment group, no significant difference was observed between them for the power output, time, ventilation volume, relative maximum oxygen uptake and $\dot{V}_E/\dot{V}O_2$ ratio on the pre test. The absolute maximum oxygen uptake of the ITG proved to be significantly higher than that of the ATG on the pre test. Since the treatment groups were initially equated on the basis of their relative maximum oxygen uptakes, only this variable will be selected to discuss which treatment was the most effective.

In the TG, the relative maximum oxygen uptake increased from 39.9 ml/kg/min on the pre test to 45.8 ml/kg/min on the post test - an overall increase of 14.8%. In the ATG and ITG, the values increased by 19.6% and 13.5% respectively - from 40.4 ml/kg/min and 41.5 ml/kg/min on the pre test to 48.3 ml/kg/min and 47.1 ml/kg/min on the post test respectively.

The post training comparisons revealed that the mean maximum oxygen uptakes of the three training groups were significantly higher than those of the CG but were not significantly different from each other. This indicates that all three training intensities were equally effective in bringing about increases in the maximum oxygen uptake. These results are in agreement with those reported by Eddy et al. (29) who observed no significant difference in the improvement in the relative maximum oxygen uptake between a continuous training group that trained at seventy percent of the maximum oxygen uptake and an interval training group that trained at one-hundred percent of the maximum oxygen uptake with work:rest intervals of one minute each. The training intensity of the continuous group was quite similar to that of the ATG in this study while that of the interval training groups in the two studies was identical. Moreover, these researchers also equated the two groups for their pre training maximum oxygen uptakes and the total amount of work done per training session as was done in this study. The stance taken by the American College of Sports Medicine (1) on the improvement in the maximum oxygen uptake with training also indicates that if the training intensity is above a minimum threshold (fifty percent of the maximum oxygen uptake), then the increase in the maximum oxygen uptake as a result of different training intensities is similar as long as the total amount of work done is the same. Although there was no significant difference between the three experimental groups in the post training maximum oxygen uptakes, the ATG seemed to be the most effective because: (1) it resulted in the highest overall actual and percentage increase and (2) the increase was significant between the mid and pre tests as well as between the post and mid tests. In the TG

and ITG, the increase in the maximum oxygen uptake was significant between the mid and pre tests but not between the post and mid tests.

The changes in the maximum oxygen uptake discussed above were for the pooled values of the two fitness categories because the non-significant triple interaction indicated that both the fitness categories responded similarly to each of the training intensities. However, the results in Table 22 indicate that when the absolute or relative maximum oxygen uptakes of the four treatment groups were pooled in each fitness category, the low fit category showed a significantly larger increase than the high fit category.[4] These results seem to agree with the report by Pollock (88) who claims that the increase in the maximum oxygen uptake with training is inversely related to the initial maximum oxygen uptake. In other words, individuals who have lower maximum oxygen uptakes prior to training will show larger improvements and vice versa.

The maximum ventilation volume was defined as the ventilation volume at the exercise intensity at which the maximum oxygen uptake was reached during the graded exercise test. This value was observed to increase significantly in the three training groups but not in the CG. In each of these training groups, the maximum increased was observed in

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[4]When the AC interaction term in considered, the levels of B are collapsed. Therefore, the pooled values of the four treatment groups in each fitness category include the values of the CG which did not show any significant change with training in either fitness category.

the first half of the training program and therefore the difference between the mid and pre tests was significant. The increase in the maximum ventilation volume in the second half of the training program was considerably less than that observed in the initial half and consequently the difference between the post and mid tests was insignificant. It is interesting to note that a major portion of the increase in the absolute maximum oxygen uptake also occurred in the initial half of the training program. The increase in the maximum oxygen uptake in the latter half of the training program was significant only in the ATG despite a non-significant increase in the maximum ventilation volume during this period. This indicates that the maximum ventilation volume is not necessarily a factor that limits the improvement in the maximum oxygen uptake.

The maximum $\dot{V}_E/\dot{V}O_2$ ratio showed no significant change as a result of the three training intensities indicating that the increases in the maximum ventilation volume and maximum oxygen uptake were proportional to each other. In order words, the three training intensities did not effect the oxygen cost of ventilation at the maximum oxygen uptake. These results are not in agreement with those reported by Bradley et al. (10) and Davis et al. (22) who observed significant decreases in the maximum $\dot{V}_E/\dot{V}O_2$ ratios subsequent to endurance training programs.

(2) Threshold One

The individual values of the power output at Th.1 (Table 41, Appendix C) were not always consistent for the three test trials in the CG. In the eight control subjects whose data was utilized for this statistical analysis, an increase in the power output was observed in four instances, a decrease in one instance and no change was recorded in

the remaining three instances for comparisons between the pre and post tests. The increase or decrease was always equivalent to 180 KPM/min. Similar variations in the power output at the MEC were observed in the CG. The means for the pre, mid and post tests were 675 KPM/min, 720 KPM/min and 743 KPM/min respectively. The overall result was a slight but insignificant increase in the power output at this threshold in the CG. In the three training groups, a significant increase in the power output at Th.1 was observed when the pre and post training means were compared. In the TG the pre, mid and post training means were 653 KPM/min, 720 KPM/min and 810 KPM/min respectively. In the ATG the corresponding values were 698 KPM/min, 742 KPM/min and 810 KPM/min, while for the ITG these values were 765 KPM/min, 765 KPM/min and 855 KPM/min. Unlike the improvement in the power output at the MEC, the difference between the mid and pre tests as well as between the post and mid tests was insignificant. Although all three training groups showed a significant improvement in the mean power output at this threshold, this increase wasn't observed in each individual. Of the eight subjects in the TG, an increase was observed in six cases while no change was observed in the remaining two cases. In each of the remaining two groups, an increase was observed in four subjects while no change was recorded in the remaining four subjects. Overall, of these twenty-four subjects who undertook the training program, an improvement in the power output at Th.1 was observed in only fourteen or fifty-eight percent of the cases. In contrast, the power output at the MEC showed an improvement in one-hundred percent of the cases.

Although the four treatment groups in each fitness category were initially equated on the basis of their relative maximum oxygen uptakes,

the statistical analysis also revealed that the pre training power output at Th.1 was not significantly different between these groups in each fitness category or when the two fitness categories were combined. The post training comparisons between the four treatment groups revealed that: (1) the three training groups had mean power outputs that were not significantly different from each other indicating that each of these was equally effective in bringing about a change in the power output at Th.1 and (2) the mean values of the three training groups were not significantly different from that of the CG. This was probably because the CG did show a slight but insignificant improvement with each test trial which tended to minimize the differences between this group and the three training groups.

As a consequence of the significant increase in the power output at Th.1 in the three training groups, the time and ventilation volume at this threshold also increased significantly in these groups. Surprisingly, these two variables increased significantly in the CG even though the increase in the power output in this group was insignificant. No significant differences between any of the four treatment groups were observed on the pre, mid or post tests for both these variables. The overall effect of training on the oxygen consumption at Th.1 was slightly different from that reported for the power output, time and ventilation volume. The absolute and relative oxygen consumptions increased significantly only in the two groups that trained continuously - the larger increase in both instances being observed in the TG (19.6%). As was the case for the power output at this threshold, the increase in the oxygen consumption observed in the TG and ATG was not of a sufficient magnitude to cause the post training values to be significantly

different from that of the CG. Moreover, the increases in the power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption observed at this threshold as a result of training were proportional to the increases in these variables at the MEC because no significant change was observed when the values at Th.1 were expressed as percentages of the values at the MEC.

In contrast to the other variables discussed, the $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 showed no significant change in the training groups or in the CG indicating that the increases in the ventilation volume and absolute oxygen consumption observed in the former groups were proportional to each other. Moreover, the inter-group comparisons revealed that none of them were significantly different from each other on any of the three tests. These results indicate that when the ventilation is functioning most efficiently in terms of oxygen cost, it is unlikely that short term physical training of the intensities utilized in this study will alter this degree of efficiency. The effect of training on the power output and $\dot{V}_E/\dot{V}O_2$ ratio at Th.1 for the single subject in Figure 2 is illustrated in Figure 12. In this particular case, the power output increased by 180 KPM/min on each test trial, but the $\dot{V}_E/\dot{V}O_2$ ratio showed a minimal change when the pre vs. post test values were compared (27.7 vs. 27.1). As already discussed, the change in the power output at this threshold was not characteristic of all the subjects that undertook the training program, while that observed in the $\dot{V}_E/\dot{V}O_2$ ratio was quite typical of these subjects.

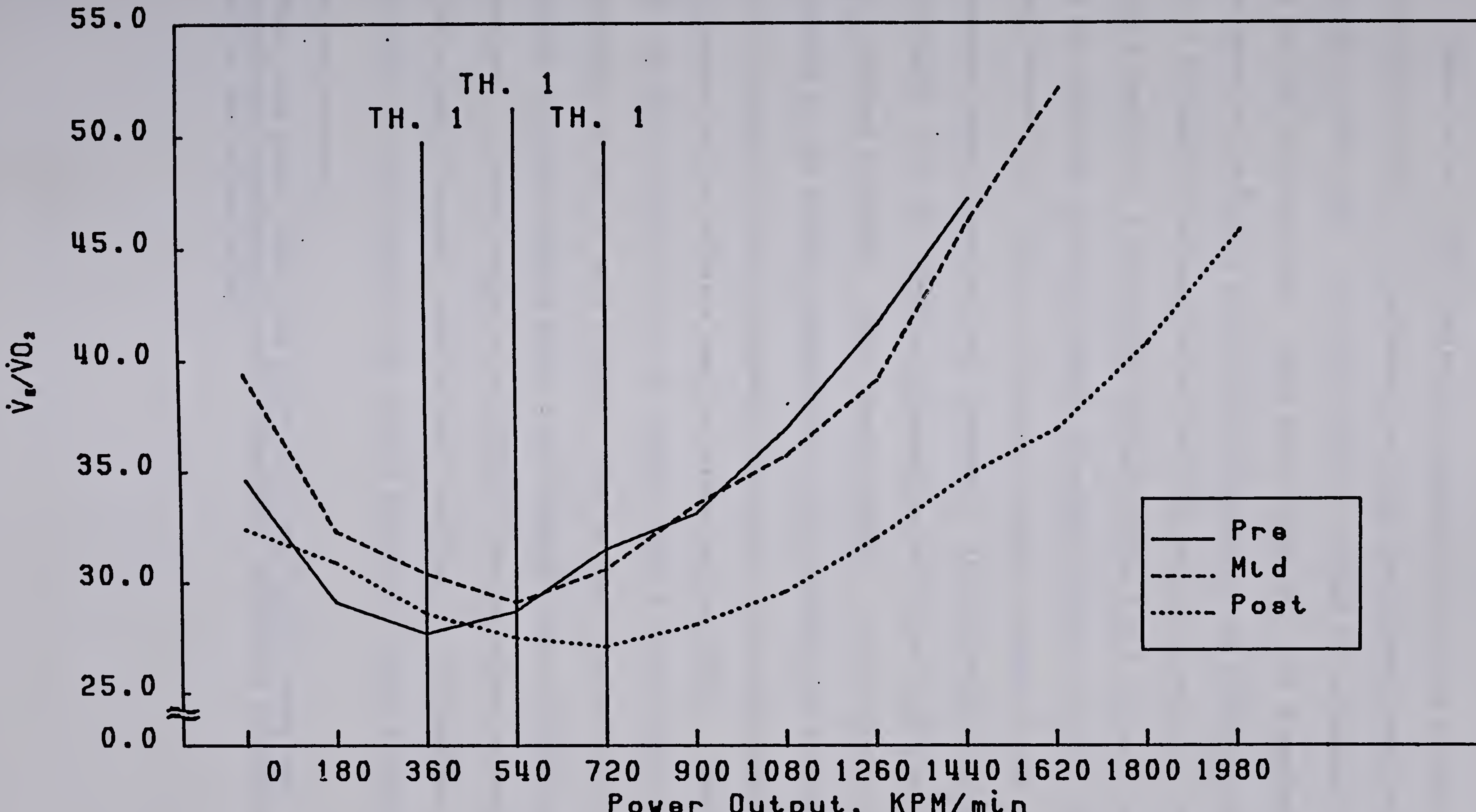

Figure 12 – The Effect of Training on the Power Output and $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One for One Subject

Davis et al. (22) studied the changes in the AT as a result of forty-five minutes of continuous training, four times a week for a period of nine weeks. The nine subjects trained at an intensity similar to the ATG in this study. Using the criteria of: (1) a systematic increase in the $\dot{V}_E/\dot{V}O_2$ ratio and no increase in the $\dot{V}_E/\dot{V}CO_2$ ratio and (2) a systematic increase in the end-tidal partial pressure of oxygen (which results in a systematic increase in the F_EO_2) without a decrease in the end-tidal partial pressure of carbon dioxide to detect the AT, they observed 0.60 l/min or forty-four percent increase in the absolute oxygen uptake at this threshold. In this study, Th.1 was considered to be the exercise intensity at which the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 reached a minimum. Using these criteria, a 0.14 l/min or 10.3% increase in the oxygen consumption at this threshold was observed. One of the reasons for the discrepancy between the two studies could be the difference in the criteria used for detecting the AT/Th.1. Considering the raw data in Table 34 for one subject (Rank 2 in the ATG, low fit category), it can be seen that according to the criteria used in the two studies, the pre training AT/Th.1 was attained after 4.0 minutes of exercise at a power output of 540 KPM/min[5] and an oxygen consumption of 1,249 ml/min. However, when the post training data is examined, according to the criteria used in this study, Th.1 again occurred after

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[5]Since this power output was below Th.2, the $\dot{V}_E/\dot{V}CO_2$ ratio was continuously decreasing, thereby completely satisfying criterion (1) used by the authors cited.

4.0 minutes of exercise at a power output of 540 KPM/min and an oxygen consumption of 1,421 ml/min. Using the criteria of Davis et al. (22), a systematic or continuous increase in the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 seemed to occur after 5.5 minutes of exercise at a power output of 900 KPM/min and an oxygen consumption of 1,742 ml/min. Hence, according to this study, the subject showed no increase in the power output and a 13.7% increase in the oxygen consumption at this threshold, whereas according to the authors cited, this subject would have increased his power output and oxygen consumption at this threshold by 66.7% and 39.5% respectively. Thus, it can be seen from this discussion, how different values for selected variables can be reported at the AT/Th.1 if different criteria are used for its detection. The physiological significance of the criteria used in this study for the detection of this threshold was mathematically justified in Section A of this chapter.

Other reasons for the large increases in the oxygen consumption at this threshold observed by Davis et al. (22) could be: (1) the lower pre training maximum oxygen uptake of the subjects in the study cited - 29.1 ml/kg/min (2.77 l/min) compared to 40.4 ml/kg/min (3.00 l/min) for the eight subjects in the ATG, high and low fit combined. It should be noted that despite the lower maximum oxygen uptake of the former subjects, the absolute value of the oxygen consumption reported at the AT, 1.36 l/min, was almost identical to that reported at Th.1 for the ATG in this study, 1.35 l/min (2) the greater frequency and duration of training of the subjects in the study cited and (3) the difference in the test protocol between the two studies being compared. In this study the power output was increased by 180 KPM/min every minute,

whereas in the study cited the increment was 90 KPM/min every minute. It is quite possible that in this study had the increment in the power output not been quite as large, the subjects would have reached Th.1 at a higher power output and oxygen consumption thereby resulting in larger overall increases with training.

Sady et al. (92), who detected the AT by means of non-linear increases in the ventiliation volume, carbon dioxide production and F_EO_2, observed a significant increase in the oxygen consumption at this threshold when the training intensity was above it (approximately eighty percent of the maximum oxygen uptake). When the training intensity was below this threshold (approximately forty percent of the maximum oxygen uptake), no significant increase in its oxygen consumption was observed, nor was the post training value significantly different from that of a control group which showed a 0.14 l/min or 10.9% (insignificant) decrease in this value. In this study, the group that trained at the lowest intensity (slightly above fifty percent of the maximum oxygen uptake in both fitness categories), namely the TG, did show a significant improvement in the oxygen consumption at Th.1, but this improvement was not of a sufficient magnitude to cause the values to differ significantly from those of the CG which showed a 0.08 l/min or 6.0% (insignificant) increase during this period. The same was true for the other two training intensities utilized in this study. It seems, therefore, that short term physical training of the frequency, intensity and duration utilized in this study is insufficient to cause a "real" change in any of the variables selected at Th.1, even though it does result in significant changes in most of these variables at the MEC.

(3) Threshold Two

The CG showed no significant change in the power output at Th.2 between the three test trials. The mean value on the mid test was identical to that observed on the pre test, 1,148 KPM/min, while the post test mean of 1,103 KPM/min was 3.9% less than the pre and mid test means. From Table 47 Appendix C, it can be seen that the power output at this threshold was not very consistent in this group of subjects. In the eight subjects whose data was utilized for the statistical analysis, comparisons between the pre and post tests revealed that the power output decreased in three subjects, increased in two subjects and was unchanged in three subjects. The increases or decreases were always of the magnitude of 180 KPM/min. These variations in the power output at Th.2 in the CG were similar to those observed at Th.1 and the MEC. In the three training groups, the power output increased significantly on each trial except in the TG where the difference between the mid and post tests was insignificant. All three training intensities were equally effectively in increasing the power output at this threshold. However, unlike the increase in the power output at Th.1, the increases observed at this threshold were: (1) due to increases in all but two of the subjects in the high fit category and (2) sufficient to result in the post training mean values of the training groups to be significantly different from those of the CG. Figure 13 illustrates the effect of training on the power output at Th.2 for the single subject in Figure 4.

The significant increase in the power output at Th.2 observed as a result of training resulted in a significant increase in the time, ventilation volume and oxygen consumption (absolute and relative) at

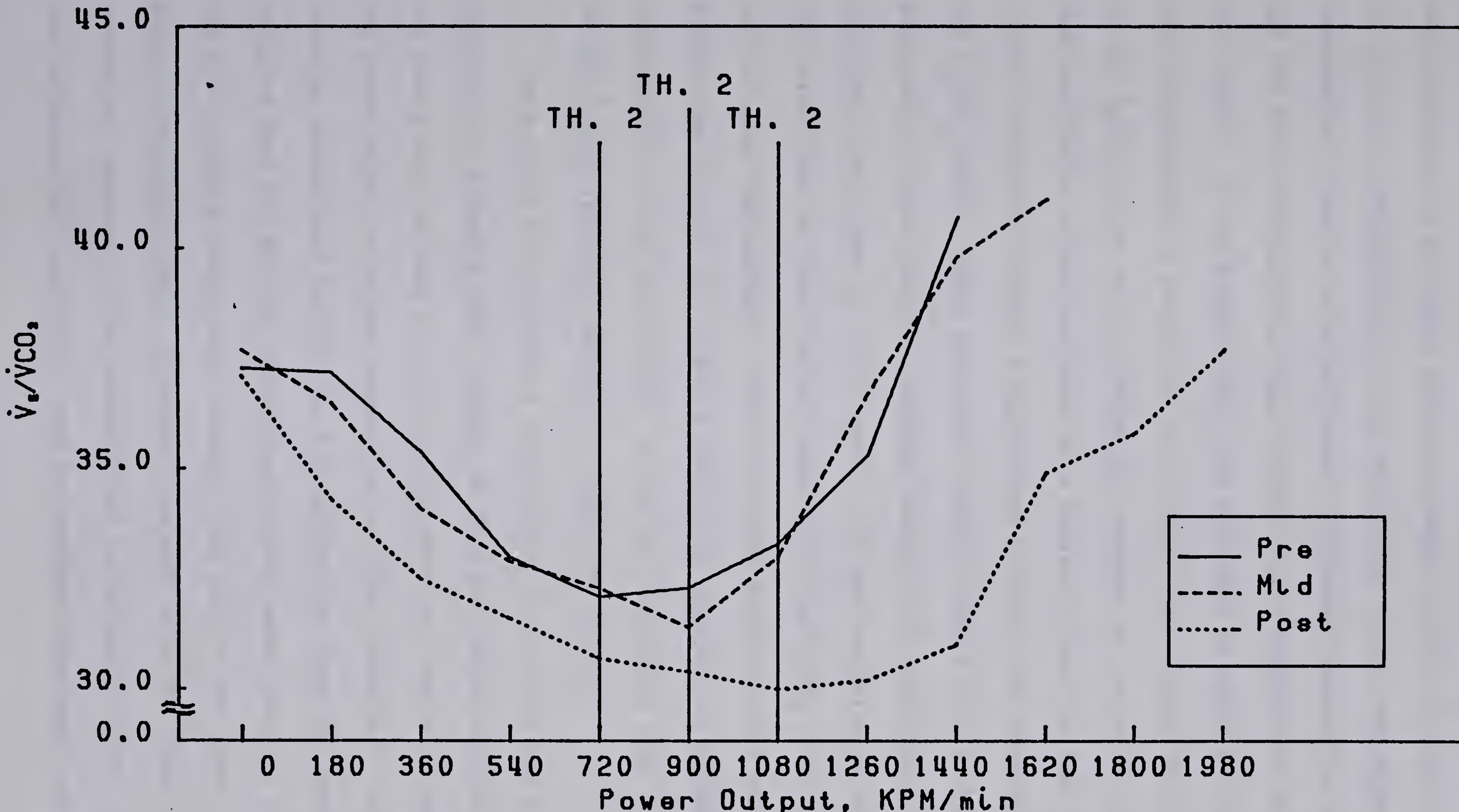

Figure 13 - The Effect of Training on the Power Output at Threshold Two for One Subject

this threshold in all three training groups. In the TG, only the pre vs. post test comparisons for the ventilation volume and oxygen consumption proved to be significantly different, whereas in the ATG and ITG the differences in these variables were significant on each test trial. In the former group, the increases in these two variables were proportional to each other as no significant change was observed in the $\dot{V}_E/\dot{V}O_2$ ratio at this threshold, whereas in the latter groups, the ventilation volume increased by a greater proportion than the oxygen consumption because a significant increase was observed in the $\dot{V}_E/\dot{V}O_2$ ratio. These increases, however, were not of a sufficient magnitude to cause the post training values to be significantly different from those of the TG and CG. It was demonstrated earlier in this study that at power outputs above Th.1 the $\dot{V}_E/\dot{V}O_2$ ratio increased more or less continuously. Since the power output at Th.2 was always higher than that at Th.1 and the former was observed to increase considerably in the ATG and ITG, it was not surprising that an increase in the $\dot{V}_E/\dot{V}O_2$ ratio was observed in these two groups.

The problem of determining which method of training was the most effective in bringing about changes at Th.2 was rather difficult because the four groups in each fitness category were not initially equated for the power output or oxygen consumption at this threshold. The pre training comparisons between the four groups for these two variables revealed that the ATG had significantly lower means than the TG and ITG. The post training comparisons revealed that none of the three training groups were significantly different from each other for these two variables. However, if the absolute and percentage increases in these two variables are considered, then the maximum improvement was observed

in the ATG. In this group, the percentage increases in the power output and absolute oxygen consumption were 51.0% and 42.1% respectively. For the ITG, these values were 33.3% and 24.2% respectively while for the TG, they were 19.9% and 12.8% respectively. Although these percentage increases were for the high and low fit categories combined, similar increases were observed when the two fitness categories were considered separately, or when the values of the four treatment groups in each fitness category were pooled.

Another method of determining which training intensity was the most effective was to study the changes in these variables when their values were expressed as percentages of the corresponding variables at the MEC. From Table 31 it can be seen that in the ATG, the oxygen uptake at Th.2 increased from 63.2% of the maximum oxygen uptake prior to training to 76.5% following training. This increase was significant on the basis of the analysis of variance but not on the basis of the Greenhouse-Geisser conservative test that was applied subsequent to the analysis of variance. In the ITG, the value increase from 69.8% to 75.3% - this increase was insignificant on the basis of the analysis of variance as well as the conservative test. In the TG, the value decreased from 77.5% prior to training to 76.8% following training - a change that was insignificant on the basis of the analysis of variance as well as the conservative test. Although none of the training groups passed the conservative test, the ATG seemed to be the most effective because it increased significantly on the basis of the analysis of variance whereas the other two groups showed no significant change on this basis. This could be due to the fact that the pre training value of the ATG was the lowest of all the four subgroups - significantly lower than that of the

TG to be more specific.

Astrand and Rodahl (3) state that it is possible to work for prolonged periods of time when the blood lactate concentration is low. This was supported by the fact that the subjects in the TG in this study, who trained at an oxygen consumption that was approximately ten percent above that at Th.1 (intensity at which a significant amount of lactic acid accumulates in the blood), were all able to complete their thirty minute training sessions without experiencing any real physical problems (see Comments on Training Program). Wenger and Reed (124) indicate that the primary cause of muscular fatigue under both aerobic and anaerobic conditions is a decrease in intramuscular pH. This was supported by the fact that the subjects in the ATG, who trained at an oxygen uptake that was fifty percent between that at Th.1 and the MEC or approximately ten percent above that at Th.2 (intensity at which the capillary pH begins to decrease significantly), were initially unable to complete their training sessions in one attempt and experienced a great deal of discomfort throughout the training program. These observations indicate that it is important for individuals who are interested in performing well in aerobic or anaerobic events to have a high power output and oxygen consumption at Th.2, while these values at Th.1 are of lesser importance. However, the correlations discussed in Section C indicate that both these variables at the two thresholds are significantly related to each other, which in turn, are related to the values at the MEC. It is interesting to note that the improvements as a result of training were more pronounced at Th.2 than at Th.1.

<u>Effect of the Four Treatments on the Ventilation Volume, Oxygen Consumption, Carbon Dioxide Production, $\dot{V}_E/\dot{V}O_2$ Ratio, $\dot{V}_E/\dot{V}CO_2$ Ratio and F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output</u>

The $\dot{V}_E/\dot{V}O_2$ ratio, as discussed above, remained unchanged at Th.1 and the MEC as a result of training in all three groups but increased significantly at Th.2 in the ATG and ITG. However, when this ratio was studied at the pre training MEC power output, a significant decrease was observed in the three training groups while no change was observed in the CG. The results in Table 32 indicate that the decrease in the $\dot{V}_E/\dot{V}O_2$ ratio was significant between each of the test trials only in the two groups that trained continuously, whereas in the ITG, the decrease was significant only between the pre and post test comparisons. Although there was no significant difference in the $\dot{V}_E/\dot{V}O_2$ ratio between the three training groups on the post test, it cannot be concluded that all three methods of training were equally effective in reducing this ratio because the pre training value was significantly higher in the ATG than in the TG and ITG. If the absolute and percentage decreases were considered, the ATG seemed to be the most effective method of training. This group showed a 27.5% decrease in this ratio while the TG and ITG showed decreases of 24.5% and 14.1% respectively.

The effect of training on the $\dot{V}_E/\dot{V}O_2$ ratio for the subjects in the ATG of the low fit category is illustrated in Figure 14. As can be seen, the curve shifted downwards and towards the right with a minimal change in the value at Th.1 and the MEC. The curves indicate that subsequent to training, the $\dot{V}_E/\dot{V}O_2$ ratio reached its minimum value (Th.1) at a higher power output with the rate of the subsequent

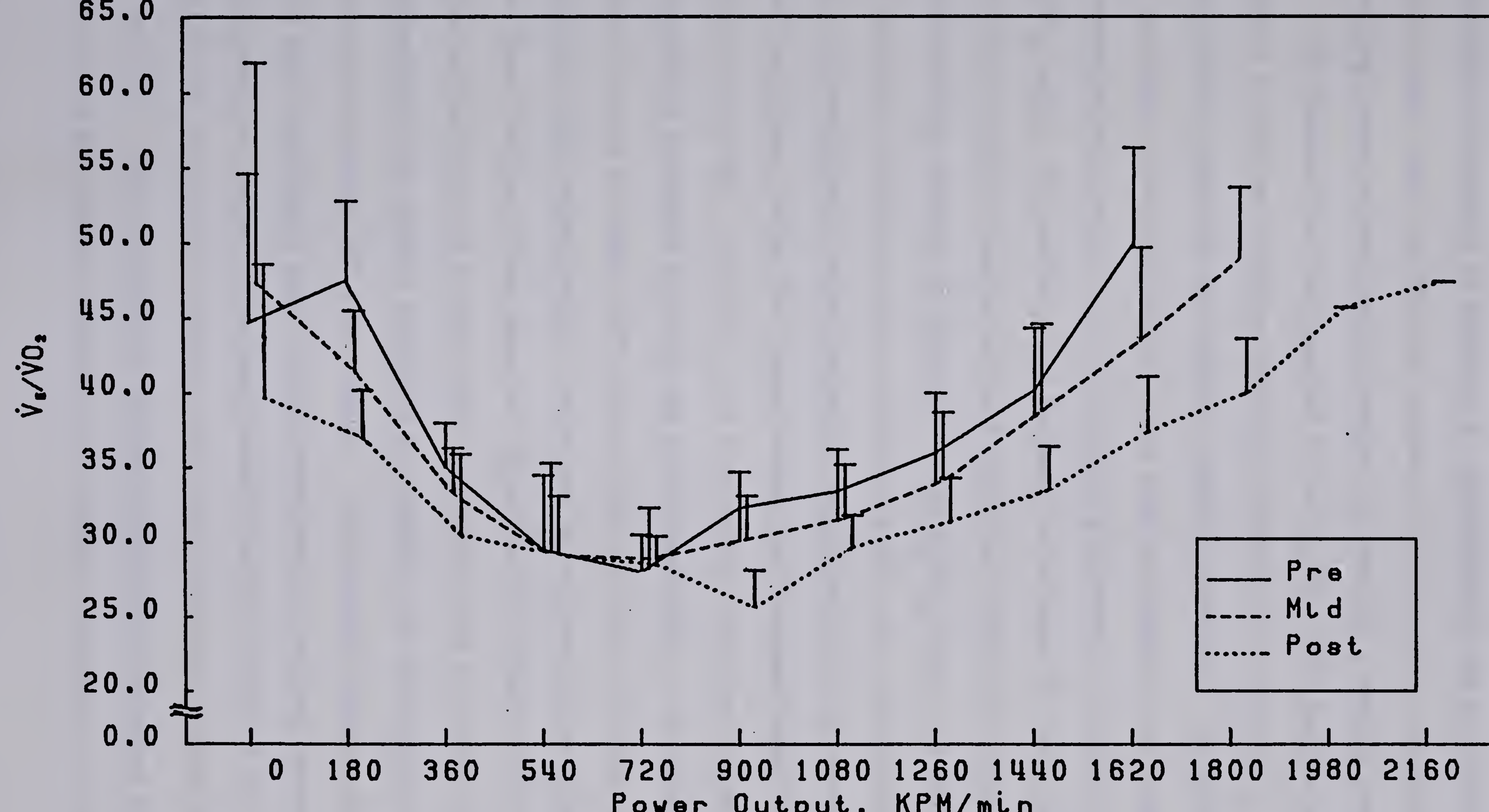

Figure 14 - The Effect of Training on the $\dot{V}_E/\dot{V}O_2$ Ratio for the Subjects in the Above Threshold Group (Low Fit Category)

inclination beginning to decrease at approximately the pre training Th.2 power output until the MEC was reached. The curves for the other training groups showed similar changes but were of a smaller magnitude.

Any changes that are observed in the $\dot{V}_E/\dot{V}O_2$ ratio are due to changes in the two variables directly effecting this ratio, i.e. the ventilation volume and the absolute oxygen consumption. An increase or decrease in the ventilation volume with no change in the oxygen consumption will result in a corresponding increase or decrease in the $\dot{V}_E/\dot{V}O_2$ ratio. In contrast, any increase or decrease in the oxygen consumption with no change in the ventilation volume will result in a corresponding decrease or increase in the $\dot{V}_E/\dot{V}O_2$ ratio. An examination of these two variables at the pre training MEC power output revealed that the ventilation volume decreased significantly in all three training groups, while the oxygen consumption decreased significantly in the TG and ITG. In the TG, the ventilation volume and oxygen consumption decreased by 23.9% and 6.6% respectively. The corresponding values for the ATG were 23.5% and 4.0% while for the ITG these were 19.8% and 8.8% respectively. The values of the ventilation volume in the three training groups were not significantly different from each other on the pre, mid or post tests indicating that all three training intensities were equally effective in reducing the ventilation volume at the pre training MEC power output. The decreased oxygen consumption at a given submaximal power output subsequent to training observed in this study is contrary to several reports in the literature (21, 22, 30, 43, 93, 94), but in agreement with the results reported by Eddy et al (29). These researchers observed significant decreases ranging between six and fifteen percent in the oxygen consumption at the same

absolute power outputs in two groups of subjects that trained continuously and intermittently for seven weeks on the bicycle ergometer. The only explanation that the author of this study can offer for his results is that the subjects who underwent training became mechanically more efficient at riding the bicycle ergometer, thus enabling them to consume a lower volume of oxygen at the same submaximal power output on the subsequent tests. This was indirectly supported by the fact that the CG showed no significant change in the oxygen consumption between the pre, mid and post tests at the pre training MEC power output. Despite the decrease in the oxygen consumption which normally would increase the $\dot{V}_E/\dot{V}O_2$ ratio for a given ventilation volume, a significant decrease in this ratio was observed in the three training groups. This was because the magnitude of the decrease in the ventilation volume was greater than that of the oxygen consumption. A decrease in the $\dot{V}_E/\dot{V}O_2$ ratio due to a decreased ventilatory drive at submaximal power outputs following training is in agreement with the results reported by Davis et al. (22), Dempsey et al. (26), Girandola (43) and Jirka and Adamus (59) but contrary to those reported by Saltin et al (94). These investigators observed no significant decrease in the ventilation volume and hence the $\dot{V}_E/\dot{V}O_2$ ratio at a submaximal power output in forty-two sedentary, middle aged men who completed an eight to ten week combined continuous and interval running program. The reason for their conflicting results may be due to the fact their training mode (running) was different from their testing mode (bicycling).

In section A, the linear relationship between the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 was discussed and the regression equation for predicting the former

from the latter was given. Since the $\dot{V}_E/\dot{V}O_2$ ratio at the pre training MEC power output decreased significantly in all three training groups, one would also expect to observe a decrease in the F_EO_2 at this power output in each of these groups. An examination of the mean F_EO_2 values in the three training groups showed that the values decreased significantly from: (1) 17.11% to 16.77% to 16.20% in the TG (2) 17.37% to 17.07% to 16.48% in the ATG and (3) 16.91% to 16.69% to 16.31% in the ITG on the pre, mid and post tests respectively. The CG, which showed a slight but insignificant increase in the $\dot{V}_E/\dot{V}O_2$ ratio from 39.8 to 41.4 to 40.4 on the pre, mid and post tests respectively, showed no significant change in the F_EO_2. The values for the three respective tests were 17.36%, 17.44% and 17.32%. These results indicate that changes in the $\dot{V}_E/\dot{V}O_2$ ratio at a given power output as a result of training can be detected by accurately monitoring the F_EO_2 values at that power output.

It is generally agreed that the primary stimuli for ventilation at high work intensities are both related to the production of lactic acid (2, 70, 106, 107, 110-112, 115). These are: (1) the increased hydrogen ion concentration or decreased pH caused by the reduction in bicarbonate concentration and (2) the "excess" amount of carbon dioxide produced as a result of the buffering of lactic acid by bicarbonate. In this study, the lactic acid or hydrogen ion concentration was not measured. However, a decreased lactic acid concentration at a submaximal power output subsequent to continuous and/or interval training that results in a significant improvement in the maximum oxygen uptake is a well established fact (29, 40, 51, 52, 93, 94, 96, 98, 130). If a decrease in the blood lactic acid concentration did occur in this study, then one

would expect to see a decrease in the volume of carbon dioxide produced at a submaximal power output. The results in Table 32 indicate that a decrease in the volume of carbon dioxide produced and the $\dot{V}_E/\dot{V}CO_2$ ratio at the pre training MEC power output was observed in all three training groups but not in the CG. The former results are in agreement with those reported by Taylor (108) while the latter are contrary to those reported by Davis et al. (22) who found that the $\dot{V}_E/\dot{V}CO_2$ ratio remained unchanged after nine weeks of endurance training despite a significant decrease in the ventilation volume at the same submaximal power output. A cross sectional study reported by Martin et al. (73), however, indicates that the $\dot{V}_E/\dot{V}CO_2$ ratios at the same relative power outputs below and above the AT were significantly lower in endurance athletes compared to non-athletes.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The purposes of this study were to: (1) examine whether two distinct ventilatory thresholds existed during a graded exercise test on a bicycle ergometer prior to reaching the MEC by monitoring selected respiratory gas exchange variables as suggested in the literature (2) compute the correlations between: (a) the two thresholds and (b) each of these thresholds and the MEC for six variables namely, the power output, time, ventilation volume, absolute oxygen consumption, relative oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio (3) compare the values of each of these variables at the two thresholds in a group of high and low fit subjects (4) study the effects of three training intensities on each of these variables at the two thresholds and (5) examine whether the two fitness categories reacted differently to the three training intensities for the selected variables at the two thresholds.

Forty male volunteers were subjected to a graded exercise test on three different occasions: prior to training, after twelve training sessions and after twenty-four training sessions. The training and testing was completed within a ten week period. The subjects exercised for four minutes at 0 KPM/min after which the power output was increased by 180 KPM/min every minute until the MEC was reached - i.e. until the subject reached his maximum oxygen uptake or was unable to exercise at the prescribed rate of sixty rpm. The respiratory gas exchange

variables that were continuously monitored during the three tests were: ventilation volume, oxygen consumption, carbon dioxide production, respiratory exchange ratio, F_EO_2 and F_ECO_2. Based on the results of the initial test, the subjects were ranked in descending order of their relative maximum oxygen uptakes. The top twenty were classified as the high fit category while the bottom twenty were classified as the low fit category. For each subject, the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ ratios were calculated at each power output and the values were plotted graphically along with the F_EO_2 and F_ECO_2 values. The twenty subjects in each fitness category were then subdivided into four treatment groups by the technique of stratified randomization so that their initial relative maximum oxygen uptakes were equalized. Each subgroup in the two fitness categories was subjected to one of four treatments namely: (1) a Control Group (CG) which did not train (2) a Threshold Group (TG) which trained for thirty minutes at an oxygen consumption that was approximately ten percent above that at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum (3) an Above Threshold Group (ATG) which trained at an oxygen consumption that was approximately fifty percent between that at which the $\dot{V}_E/\dot{V}O_2$ ratio reached a minimum and the maximum oxygen uptake and (4) an Interval Training Group (ITG) that trained at one hundred percent of the maximum oxygen uptake with work:rest intervals of one minute each. The total work done by each group per training session was equalized. The design corresponded to a three factor experiment in which Factor A was the two fitness categories of subjects, Factor B was the four treatments in each fitness category and Factor C was the measurement on the three test trials. The statistical analysis used to study the difference between the two fitness categories and the effects

of the different treatments was a three-way analysis of variance with repeated measures on the last factor, coupled with the Greehouse-Geisser conservative test. A post hoc Scheffe test was used to locate significant differences between the fitness categories, test trials and treatment groups in each case.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1) Two distinct thresholds were detected during the course of the graded exercise test prior to reaching the MEC. The first threshold, termed Threshold One (Th.1) in this study, was characterized by the power output at which the $\dot{V}_E/\dot{V}O_2$ ratio and F_EO_2 reached a minimum. The second threshold, termed Threshold Two (Th.2) in this study, was characterized by the power output at which the $\dot{V}_E/\dot{V}CO_2$ ratio reached a minimum and the F_ECO_2 reached a maximum. The $\dot{V}_E/\dot{V}O_2$ ratio and the F_EO_2 were linearly related to each other while the $\dot{V}_E/\dot{V}CO_2$ ratio and the F_ECO_2 were inversely related to each other. The power output, time, ventilation volume, absolute oxygen consumption, relative oxygen consumption and $\dot{V}_E/\dot{V}O_2$ ratio at Th.2 was always greater than that at Th.1.
2) Correlations computed for the selected variables between: (a) the two thresholds and (b) each of these thresholds and the MEC were usually significant when the entire sample was considered. The values at Th.2 were more closely related to those at the MEC than the values at Th.1.
3) The high fit subjects had higher absolute and relative oxygen

consumptions at both the thresholds than the low fit subjects. No significant difference was observed between the two fitness categories for the other four variables at the two thresholds. No significant differences were observed between the two fitness categories when the values of each of these variables at the two thresholds were expressed as percentages of the values at the MEC.

4a) All three training intensities were capable of significantly increasing the power output, time and ventilation volume at Th.1. Only the continuous training groups resulted in significant increases in the absolute and relative oxygen consumptions at this threshold. None of the increases in these variables were of sufficient magnitude to cause the values to be significantly different from those of the CG. No significant change was observed in the $\dot{V}_E/\dot{V}O_2$ ratio in any of the groups indicating that the increases in the ventilation volume and oxygen consumption at this threshold were proportional to each other.

4b) All three training intensities resulted in a significant increase in the power output, time, ventilation volume, absolute oxygen consumption and relative oxygen consumption at Th.2. The $\dot{V}_E/\dot{V}O_2$ ratio increased significantly only in the ATG and ITG. The increases in all these variables, except the $\dot{V}_E/\dot{V}O_2$ ratio, were of sufficient magnitude to cause the values to be significantly higher than those of the CG.

4c) The increases observed in these variables at the two thresholds as a result of training were proportional to the increases observed at the MEC because no significant change was observed when the former values were expressed as percentages of the latter.

5) There was no significant difference between the high and low fit categories in the changes that were observed at the two thresholds and the MEC as a result of training.

6a) All three training intensities resulted in significant decreases in the $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ ratios at the pre training MEC power output. The decrease in these ratios was attributed primarily to a decreased ventilatory drive as a result of a decrease in the volume of carbon dioxide produced at this power output.

6b) The decrease in the $\dot{V}_E/\dot{V}O_2$ ratio at the pre training MEC power output could be detected by a corresponding decrease in the F_EO_2 at the same power output.

Thus, the study showed that two distinct ventilatory thresholds occurred during a graded exercise test prior to reaching the MEC. The training intensities were capable of inducing considerable changes primarily at Th.2 and the MEC while those at Th.1 were of a lesser magnitude. All three intensities appeared to be equally effective in inducing the changes at the three reference points in both fitness categories, provided the total power output of each training group was the same.

Recommendations

It is recommended that the effect of long term physical training of various frequencies, intensities and durations on the two thresholds be studied more extensively in a wide cross section of subjects. Detraining studies also should be conducted to determine the time course of the reversal of the changes that occur as a result of such training.

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APPENDIX A

CONSENT TO VOLUNTEER IN THE STUDY

I, ____________________________ hereby agree to volunteer in a study titled, "Ventilatory Thresholds during a Graded Exercise Test: The Effect of Three Training Intensities in Males". I understand that I will be required to:

1. Perform a graded exercise test on a bicycle ergometer designed to determine my Maximum Exercise Capacity prior to the commencement of the training program, after four weeks of training and after eight weeks of training.

2. Undergo a test designed to determine by percent body fat by the hydrostatic method prior to the training program.

3. Train on a bicycle ergometer three times a week for a period of eight consecutive weeks at either a submaximal or maximal workload. The duration of each training session will be approximately thirty minutes.

I understand that with any type of exercise there are potential risks and if at any time during the tests or training I experience unusual discomfort, I will be allowed to discontinue the test. I will also be allowed to opt out of the study at any time during its course without any obligation of offering an explanation.

By agreeing to participate in such a study, I waive any legal recourse against the University of Alberta from any and all claims resulting from these fitness tests.

DATE: ________________________ SUBJECT: __________________________
(Signature)

WITNESS: __________________________

INSTRUCTIONS TO SUBJECTS FOR TESTING SESSIONS

NAME: ______________________________

Your appointment for fitness testing is at:

TIME: ____________am/pm on DATE: ________________________________

Please read the following instructions carefully.

1. Report to the strength and endurance laboratory RM. E - 440, located on the 4th Floor in the East Wing of the Physical Education building.

2. When reporting to the laboratory, please come dressed in shorts, T-shirt and running shoes. Also, bring a pair of swimming trunks and a towel with you.

3. Avoid ingesting any foods and nutrients for at least two hours prior to your scheduled testing time.

4. Avoid smoking and any vigorous physical activity for at least two hours prior to your scheduled testing time.

5. If you have to cancel your appointment, please call Yagesh Bhambhani at 432-5503, or ask the person who answers the telephone to leave a message in my mailbox.

6. If necessary, you can park your car at the Stadium Car Park.

APPENDIX B

DATA COLLECTION SHEETS

Subject Information

Name: ____
Last First

Sex: Age: yrs.

Height: cms Weight: kgs.

Occupation:

Physical Activity Patterns: Indicate below the average amount of time spent per week on physical activities such as jogging, tennis, racquetball, etc.

Have you ever been advised by a physician not to engage in vigorous physical activity?

If yes, please explain.

Graded Exercise Test Data

Name: ____________ Category: _______ Group: _______ Rank: _______ Test: _______

Pow. Out KPM/min	Time mins:secs	$\dot{V}_E$ ml/min	$\dot{V}O_2$ ml/min	$\dot{V}O_2$ ml/kg/min	V_E/VO_2	F_EO_2 %	$\dot{V}CO_2$ ml/min	V_E/VCO_2	F_ECO_2 %	R
	0:30									
0	1:00									
	1:30									
180	2:00									
	2:30									
360	3:00									
	3:30									
540	4:00									
	4:30									
720	5:00									
	5:30									
900	6:00									
	6:30									
1080	7:00									
	7:30									
1260	8:00									
	8:30									
1440	9:00									
	9:30									
1620	10:00									
	10:30									
1800	11:00									
	11:30									
1980	12:00									
	12:30									
2160	13:00									
	13:30									
2340	14:00									
	14:30									
2520	15:00									

1 = Th.1 2 = Th.2 3 = MEC

Determination of percent body fat by the underwater weighing method

Name:

Measurements:

(1) Weight in air =

(2) Vital Capacity (V.C.) = litres x 61.02 = cu. in.

(3) Residual Volume = 25% or 30% V.C. = cu. in.

(4) Volume of Gastro intestinal track (V.G.I.) = 7.01 cu. in.

(5) Weight in water = $\frac{\text{Chart Reading x belt weight}}{75}$ - belt weight

= lbs.

Calculations:

(6) Total body air (T.B.A.) = V.C. + R.V. + V.G.I. (from 2, 3, and 4 above)

= x .0362 = lbs.

(7) True weight in water = weight in water (5) + total body air (6)

= lbs.

(8) Body volume = weight in air (1) - true weight in water (7).

(9) Body density = $\frac{\text{weight in air (1)}}{\text{body volume (8)}}$ x density of water at °C.

=

(10) Percent Fat = $\frac{4.570}{\text{body density (9)}}$ - 4.142 x 100

= %

(11) Pounds fat = percent fat (10) x Wt. in air (1)

= lbs.

(12) Fat free weight = weight in air (1) - pounds fat (11)

= lbs.

Sample MMC Print Out Indicating the Anaerobic Threshold for the Subject in Figure 2

180 KPM/min	360 KPM/min	360 KPM/min	540 KPM/min
17,846. V	20,575. V	23,935. V	31,388. V
613. A	742. A	859. A	1,030. A
8.3	10.0	11.6	13.9
479. C	575. C	677. C	[illegible] C
.78 P	.78 P	.79 P	.85 R
120.00 Σ	150.00 Σ	180.00 Σ	210.10 Σ
....	....	....	....
3.59 %	3.74 %	3.79 %	3.75 %
16.57 %	16.36 %	16.37 %	16.70
32.30 C	32.30 C	32.30 C	32.30 C
697.00 P	697.00 P	697.00 P	697.00 P
8.50 V	9.80 V	11.40 V	15.00 V
30.00 T	30.00 T	30.00 T	30.10 T
$\dot{V}_E/\dot{V}O_2 = \frac{17846}{613} = 29.1$	$\dot{V}_E/\dot{V}O_2 \; \frac{20575}{742} = 27.7$[1]	$\dot{V}_E/\dot{V}O_2 = \frac{23935}{859} = 27.8$	$\dot{V}_E/\dot{V}O_2 = \frac{31388}{1030} = 30.4$
% $F_EO_2 = 16.57$	% $F_EO_2 = 16.36$	% $F_EO_2 = 16.37$	% $F_EO_2 = 16.70$

1 = Minimum value indicating the AT (Th.1)

Sample MMC Print Out Indicating the Threshold of Decompensated Metabolic Acidosis for the Subject in Figure 4

720 KPM/min	720 KPM/min	900 KPM/min	900 KPM/min
39,131. V	40,101. V	49,610. V	56,308. V
1,280. A	1,274. A	1,499. A	1,648. A
17.3	17.2	20.3	22.3
1,199. C	1,250. C	1,530. C	1,745. C
.94 R	.98 R	1.02 R	1.06 R
270.20 [illegible]	300.20 [illegible]	330.30 [illegible]	360.40 [illegible]
....	....	....	....
4.10 %	4.17 %	4.13 %	4.14 %
16.64 %	16.72 %	16.89 %	16.99 %
32.30 C	32.70 C	32.20 C	32.20 C
697.00 P	697.00 P	697.00 P	697.00 P
18.70 V	19.10 V	23.70 V	26.90 V
30.10 T	30.00 T	30.10 T	30.10 T
$\dot{V}_E/\dot{V}CO_2 = \frac{39131}{1199} = 32.6$	$\dot{V}_E/\dot{V}CO_2 = \frac{40101}{1250} = 32.1$[1]	$\dot{V}_E/\dot{V}CO_2 = \frac{49610}{1530} = 32.4$	$\dot{V}_E/\dot{V}CO_2 = \frac{56308}{1745} = 32.3$
$\% F_ECO_2 = 4.10$	$\% F_ECO_2 = 4.17$[2]	$\% F_ECO_2 = 4.13$	$\% F_ECO_2 = 4.14$

1 = Minimum value indicating the TDMA) (Th.2)
2 = Maximum value indicating the TDMA)

APPENDIX C

RAW DATA

Note: The means and standard deviations reported in Tables 35 to 68 are for a sample size of four subjects per cell on each test trial. The data of the subjects marked with asterisks (*, **) is excluded for the computations of these values. The units of measurement for the variables selected are:

Power Output = KPM/min

Time = minutes

Ventilation Volume = ml/min, BTPS

Absolute Oxygen Consumption = ml/min, STPD

Relative Oxygen Consumption = ml/kg/min, STPD

Absolute Carbon Dioxide Production = ml/min, STPD

$\dot{V}_E/\dot{V}O_2$ Ratio = $\dot{V}_E$, ml/min BTPS/$\dot{V}O_2$, ml/min STPD

$\dot{V}_E/\dot{V}CO_2$ Ratio = $\dot{V}_E$, ml/min BTPS/$\dot{V}CO_2$, ml/min STPD

F_EO_2 = %

Table 34: Raw Data for One Subject

Name: ________ Category: Low Fit Group: ATG Rank: 2

Pow. Out. KPM/min	Time mins:secs	$\dot{V}_E$ ml/min	$\dot{V}O_2$ ml/min	V_E/VO_2	F_EO_2 %	$\dot{V}_E$ ml/min	$\dot{V}O_2$ ml/min	V_E/VO_2	F_EO_2 %
	0:30	17903	475	37.7	17.42	17481	548	31.9	17.02
0	1:00	19288	571	33.8	17.08	21271	648	32.8	16.81
	1:30	20737	653	31.7	16.83	21179	681	31.1	16.63
180	2:00	21995	713	30.9	16.70	18849	631	29.9	16.38
	2:30	23977	799	30.0	16.57	26469	992	26.7	15.95
360	3:00	26343	905	29.1	16.43	26028	985	26.4	15.89
	3:30	28772	1006	28.6	16.34	29545	1132	26.1	15.95
540	4:00	33909	1249	27.1	16.08	35573	1421	25.0	15.84
	4:30	37809	1379	27.4	16.09	38530	1381	27.9	16.02
720	5:00	43244	1475	29.3	16.34	40798	1457	28.0	16.00
	5:30	51831	1716	30.2	16.44	48253	1742	27.7	15.98
900	6:00	58952	1792	32.9	16.74	53834	1914	28.1	16.00
	6:30	66465	2008	33.1	16.67	56492	1948	29.0	16.07
1080	7:00	72080	2157	33.4	16.78	63685	2181	29.2	16.09
	7:30	79169	2349	33.7	16.81	71339	2433	29.3	16.15
1260	8:00	90026	2503	35.9	17.04	71845	2421	29.7	16.20
	8:30	112249	2709	41.4	17.51	85738	2753	31.1	16.40
1440	9:00	133930	2854	46.9	17.87	98967	3009	32.9	16.58
	9:30	151364	2970	50.9	18.39	115749	3257	35.5	16.87
1620	10:00					127605	3325	38.3	17.15
	10:30					139169	3495	39.8	17.24
1800	11:00					163478	3532	46.3	17.76
	11:30					168438	3723	45.2	17.72
1980	12:00								

PRE TEST POST TEST

Table 35 - Power output at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	1980	1800	1980
	CG2**	1800	1620	1800
	CG3	1800	1800	1980
	CG4	1800	1800	1800
	CG5	1440	1620	1620
	MEAN ± SD	1755 ± 196	1755 ± 78	1845 ± 149
	TG1	1980	2160	2160
	TG2**	1440	1440	1620
	TG3	1620	1800	1800
	TG4	1440	1440	1800
	TG5	1620	1800	2160
HIGH	MEAN ± SD	1655 ± 196	1800 ± 255	1980 ± 180
	ATG1	1800	1980	2340
	ATG2*	1800	--	--
	ATG3	1800	2340	2520
	ATG4	1620	1800	1980
	ATG5	1980	2160	2340
	MEAN ± SD	1800 ± 127	2070 ± 201	2295 ± 196
	ITG1	1620	1800	1980
	ITG2**	1980	1980	2160
	ITG3	1980	2160	2340
	ITG4	1800	2160	2340
	ITG5	1980	2160	2340
	MEAN ± SD	1845 ± 149	2070 ± 156	2250 ± 156
	CG1	1620	1440	1620
	CG2**	1440	1440	1440
	CG3	1800	1800	1800
	CG4	1800	1800	1800
	CG5	1440	1440	1440
	MEAN ± SD	1665 ± 149	1620 ± 180	1665 ± 149
	TG1	1800	1980	2160
	TG2*	1440	--	--
	TG3	1620	1980	2160
	TG4	1620	1800	1980
	TG5	1440	1620	1800
LOW	MEAN ± SD	1620 ± 127	1845 ± 149	2025 ± 149
	ATG1	1620	1800	1980
	ATG2**	1620	1800	1980
	ATG3	1620	1800	2160
	ATG4	1440	1620	1980
	ATG5	1440	1620	1980
	MEAN ± SD	1530 ± 90	1710 ± 90	2025 ± 78
	ITG1	1980	2340	2340
	ITG2**	1620	1980	2160
	ITG3	1620	2160	2340
	ITG4	1440	1620	1800
	ITG5	1620	1800	2160
	MEAN ± SD	1665 ± 196	1980 ± 284	2160 ± 220

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 36 - Time at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	11.5	11.0	11.5
	CG2**	10.5	10.0	10.5
	CG3	10.5	10.5	11.5
	CG4	10.5	10.5	10.5
	CG5	9.0	9.5	9.5
	MEAN ± SD	10.4 ± 0.9	10.4 ± 0.5	10.8 ± 0.8
	TG1	11.5	12.5	13.0
	TG2**	9.0	9.0	9.5
	TG3	9.5	10.5	10.5
	TG4	9.0	9.0	11.5
	TG5	9.5	11.0	13.0
HIGH	MEAN ± SD	9.9 ± 1.0	10.8 ± 1.3	12.0 ± 1.1
	ATG1	10.5	11.5	13.5
	ATG2*	11.0	--	--
	ATG3	10.5	13.5	14.5
	ATG4	9.5	10.5	11.5
	ATG5	11.5	12.5	13.5
	MEAN ± SD	10.5 ± 0.7	12.0 ± 1.1	13.3 ± 1.1
	ITG1	10.0	11.0	11.5
	ITG2**	12.0	12.0	13.5
	ITG3	12.0	13.0	13.5
	ITG4	11.0	13.0	14.0
	ITG5	11.5	13.0	14.0
	MEAN ± SD	11.1 ± 0.7	12.5 ± 0.9	13.3 ± 1.0
	CG1	9.5	9.0	9.5
	CG2**	9.0	9.0	8.5
	CG3	10.5	10.5	10.5
	CG4	10.5	10.5	10.5
	CG5	8.5	9.0	9.0
	MEAN ± SD	9.8 ± 0.8	9.8 ± 0.8	9.9 ± 0.6
	TG1	10.5	11.5	13.0
	TG2*	9.0	--	--
	TG3	10.0	12.0	12.5
	TG4	9.5	10.5	10.5
	TG5	8.5	10.0	10.5
LOW	MEAN ± SD	9.6 ± 0.7	11.0 ± 0.8	11.6 ± 1.1
	ATG1	10.0	10.5	11.5
	ATG2**	9.5	10.5	11.5
	ATG3	10.0	10.5	12.5
	ATG4	9.0	10.0	12.0
	ATG5	9.0	9.5	11.5
	MEAN ± SD	9.5 ± 0.5	10.1 ± 0.4	11.9 ± 0.4
	ITG1	11.5	14.0	14.0
	ITG2**	9.5	11.5	13.0
	ITG3	10.0	13.0	14.0
	ITG4	8.5	10.0	11.0
	ITG5	9.5	11.0	12.5
	MEAN ± SD	9.9 ± 1.1	12.0 ± 1.6	12.9 ± 1.2

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 37 - Ventilation Volume at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	168375	151510	142226
	CG2**	118967	107839	117945
	CG3	122140	126597	140623
	CG4	135655	122530	130445
	CG5	111959	123851	121299
	MEAN ± SD	134532 ± 21270	131122 ± 11862	133648 ± 8441
	TG1	127308	146091	144045
	TG2**	132780	130255	150799
	TG3	100044	161148	140747
	TG4	121296	117296	137739
	TG5	115842	128030	132246
HIGH	MEAN ± SD	116123 ± 10130	138141 ± 16802	138694 ± 4340
	ATG1	128957	139222	159899
	ATG2*	173220	--	--
	ATG3	96229	148485	144342
	ATG4	102332	117489	128379
	ATG5	160615	172701	166229
	MEAN ± SD	122033 ± 25448	144474 ± 19803	149712 ± 14667
	ITG1	130202	141499	178556
	ITG2**	172255	175222	150099
	ITG3	155514	160212	170814
	ITG4	143515	171453	146680
	ITG5	115074	118692	121315
	MEAN ± SD	136076 ± 15073	147964 ± 20002	154341 ± 22400
	CG1	108276	104852	120644
	CG2**	116079	126994	106765
	CG3	135626	162609	128632
	CG4	135632	129050	131278
	CG5	72250	95195	95090
	MEAN ± SD	112946 ± 26014	122926 ± 26019	118911 ± 14299
	TG1	146981	135144	147416
	TG2*	143653	--	--
	TG3	93426	128352	140044
	TG4	109435	134638	137942
	TG5	122320	172371	151805
LOW	MEAN ± SD	118040 ± 19595	142626 ± 17380	144301 ± 5580
	ATG1	125921	129050	166449
	ATG2**	151364	164152	168438
	ATG3	141072	161442	150336
	ATG4	118148	153553	152818
	ATG5	117806	115141	151845
	MEAN ± SD	125737 ± 9430	139797 ± 18582	155362 ± 6462
	ITG1	153678	169368	183015
	ITG2**	146140	158128	171106
	ITG3	80509	133566	128874
	ITG4	125019	137689	152030
	ITG5	66961	110345	110831
	MEAN ± SD	106542 ± 34668	137742 ± 21025	143688 ± 26997

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 38 - Absolute Oxygen Consumption at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	4300	4005	3801
	CG2**	2992	3123	3163
	CG3	3342	3355	3553
	CG4	3717	3936	3625
	CG5	2795	2852	2889
	MEAN ± SD	3538.5 ± 548.5	3537.0 ± 469.2	3467.0 ± 345.7
	TG1	3948	4081	3853
	TG2**	3090	3093	3298
	TG3	3104	3563	3442
	TG4	2526	2685	2901
	TG5	3498	3874	3866
HIGH	MEAN ± SD	3269.0 ± 522.7	3550.8 ± 532.8	3515.5 ± 393.6
	ATG1	3838	4103	4041
	ATG2*	4015	--	--
	ATG3	3343	3690	3793
	ATG4	3135	3300	3404
	ATG5	3482	3935	4016
	MEAN ± SD	3449.5 ± 256.0	3757.0 ± 302.0	3813.5 ± 255.4
	ITG1	3805	3616	3811
	ITG2**	3381	4052	4004
	ITG3	3881	4514	4452
	ITG4	3761	3839	3837
	ITG5	3196	3687	3700
	MEAN ± SD	3660.8 ± 271.7	3914.0 ± 355.7	3950.0 ± 294.4
	CG1	2537	2656	2626
	CG2**	2770	2859	2609
	CG3	2931	3010	3236
	CG4	3040	3106	3088
	CG5	2208	2140	2052
	MEAN ± SD	2679.0 ± 330.1	2748.0 ± 394.7	2749.0 ± 462.2
	TG1	3262	3711	3843
	TG2*	2943	--	--
	TG3	2984	3212	3678
	TG4	2745	3343	3423
	TG5	2820	3453	3498
LOW	MEAN ± SD	2952.8 ± 198	3429.8 ± 183.4	3610.5 ± 163.1
	ATG1	2649	3206	3351
	ATG2**	2970	3476	3723
	ATG3	2494	3080	3173
	ATG4	2503	2945	3339
	ATG5	2579	2452	3124
	MEAN ± SD	2556.3 ± 62.9	2920.8 ± 285.9	3246.8 ± 99.0
	ITG1	4008	3823	4136
	ITG2**	3250	3242	3899
	ITG3	2716	3868	3704
	ITG4	2995	3696	3784
	ITG5	2477	3045	3043
	MEAN ± SD	3049.0 ± 583.2	3608.0 ± 331.1	3666.8 ± 395.1

* - Subject droppped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 39 - Relative Oxygen Consumption at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	51.6	48.0	45.8
	CG2**	49.6	51.8	52.3
	CG3	47.3	47.1	50.5
	CG4	44.5	48.9	45.6
	CG5	42.6	43.5	44.0
	MEAN ± SD	46.7 ± 3.3	46.9 ± 2.0	46.5 ± 2.4
	TG1	49.7	51.4	49.1
	TG2**	47.4	48.2	51.1
	TG3	45.7	52.1	51.0
	TG4	42.6	44.5	48.3
	TG5	42.1	47.5	46.5
HIGH	MEAN ± SD	45.0 ± 3.0	48.9 ± 3.1	48.7 ± 1.6
	ATG1	49.7	54.1	53.6
	ATG2*	47.4	--	--
	ATG3	44.5	50.3	51.6
	ATG4	44.2	46.2	47.2
	ATG5	42.5	49.2	50.8
	MEAN ± SD	45.3 ± 2.5	50.0 ± 2.8	50.8 ± 2.3
	ITG1	57.6	54.4	56.6
	ITG2**	49.6	58.1	58.9
	ITG3	44.8	51.1	50.3
	ITG4	43.1	53.4	44.4
	ITG5	42.1	48.6	49.3
	MEAN ± SD	46.9 ± 6.3	49.4 ± 4.0	50.2 ± 4.3
	CG1	39.8	42.0	41.5
	CG2**	39.0	39.7	36.9
	CG3	36.6	40.0	42.2
	CG4	34.7	35.6	35.4
	CG5	32.7	31.1	30.3
	MEAN ± SD	36.0 ± 2.6	37.2 ± 4.2	37.4 ± 4.9
	TG1	41.5	47.8	49.1
	TG2*	39.1	--	--
	TG3	35.6	38.3	44.5
	TG4	32.8	40.1	41.0
	TG5	29.2	36.7	36.8
LOW	MEAN ± SD	34.8 ± 4.5	40.7 ± 4.3	42.9 ± 4.5
	ATG1	39.8	48.1	51.8
	ATG2**	36.7	43.6	45.4
	ATG3	35.0	43.6	45.2
	ATG4	33.8	38.8	44.6
	ATG5	32.8	32.2	41.0
	MEAN ± SD	35.4 ± 2.7	40.7 ± 5.9	45.7 ± 3.9
	ITG1	42.0	40.8	43.4
	ITG2**	39.6	39.4	48.0
	ITG3	36.2	50.8	50.7
	ITG4	33.7	41.4	42.4
	ITG5	32.6	40.0	40.0
	MEAN ± SD	36.1 ± 3.6	43.3 ± 4.4	44.1 ± 4.0

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 40 - $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	39.2	37.8	37.4
	CG2**	39.8	34.5	37.3
	CG3	36.5	37.7	39.6
	CG4	36.5	31.1	36.0
	CG5	40.1	43.4	42.4
	MEAN ± SD	38.1 ± 1.6	37.5 ± 4.4	38.8 ± 2.3
	TG1	32.3	35.8	37.4
	TG2**	43.0	42.1	45.7
	TG3	32.2	45.2	40.9
	TG4	48.0	43.7	47.5
	TG5	33.1	33.0	34.2
HIGH	MEAN ± SD	36.4 ± 6.7	39.4 ± 5.1	40.0 ± 4.4
	ATG1	33.6	33.9	39.6
	ATG2*	41.1	--	--
	ATG3	28.8	40.1	38.1
	ATG4	32.6	35.6	37.7
	ATG5	46.1	43.9	41.4
	MEAN ± SD	35.3 ± 6.5	38.4 ± 3.1	39.2 ± 1.5
	ITG1	34.2	39.2	46.8
	ITG2**	50.9	43.2	37.5
	ITG3	40.1	35.5	38.4
	ITG4	38.2	44.7	38.2
	ITG5	36.0	32.2	32.8
	MEAN ± SD	37.1 ± 2.2	37.9 ± 4.6	39.1 ± 5.0
	CG1	42.7	39.5	46.0
	CG2**	41.9	44.4	40.9
	CG3	46.3	52.6	39.8
	CG4	44.6	41.5	42.5
	CG5	32.7	44.5	46.3
	MEAN ± SD	41.6 ± 5.3	44.5 ± 5.0	43.7 ± 2.7
	TG1	45.1	39.9	38.4
	TG2*	48.8	--	--
	TG3	31.3	40.0	38.1
	TG4	39.8	40.3	40.3
	TG5	43.3	49.9	43.4
LOW	MEAN ± SD	39.9 ± 5.3	42.5 ± 4.3	40.1 ± 2.1
	ATG1	47.5	40.3	49.7
	ATG2**	50.9	47.2	45.2
	ATG3	56.5	52.4	47.4
	ATG4	47.2	52.1	45.8
	ATG5	45.7	46.9	48.6
	MEAN ± SD	49.2 ± 4.3	47.9 ± 5.4	47.9 ± 1.4
	ITG1	38.4	44.3	44.2
	ITG2**	45.0	48.8	43.9
	ITG3	29.7	34.5	34.8
	ITG4	41.8	37.3	40.2
	ITG5	27.0	36.2	36.4
	MEAN ± SD	34.2 ± 6.1	38.1 ± 3.7	38.9 ± 3.6

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 41 - Power Output at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	900	900	1080
	CG2**	900	720	540
	CG3	900	900	900
	CG4	540	720	720
	CG5	540	540	540
	MEAN ± SD	720 ± 180	765 ± 149	810 ± 201
	TG1	540	720	900
	TG2**	720	720	720
	TG3	720	900	900
	TG4	540	540	900
	TG5	720	720	900
HIGH	MEAN ± SD	630 ± 90	720 ± 127	900 ± 0
	ATG1	720	720	720
	ATG2*	720	--	--
	ATG3	720	720	900
	ATG4	900	900	900
	ATG5	900	900	1080
	MEAN ± SD	810 ± 90	810 ± 90	900 ± 127.3
	ITG1	900	1080	900
	ITG2**	900	900	900
	ITG3	1080	1260	1260
	ITG4	720	720	720
	ITG5	720	540	900
	MEAN ± SD	855 ± 149	900 ± 285	945 ± 196
	CG1	540	720	720
	CG2**	540	540	540
	CG3	540	540	720
	CG4	720	720	720
	CG5	720	720	540
	MEAN ± SD	630 ± 90	675 ± 78	675 ± 78
	TG1	720	720	720
	TG2*	540	--	--
	TG3	720	720	720
	TG4	720	720	900
	TG5	540	720	720
LOW	MEAN ± SD	675 ± 78	720 ± 0	720 ± 78
	ATG1	720	720	720
	ATG2**	540	540	540
	ATG3	720	900	900
	ATG4	360	540	720
	ATG5	540	540	540
	MEAN ± SD	585 ± 149	675 ± 149	720 ± 127
	ITG1	720	720	720
	ITG2**	720	720	720
	ITG3	720	720	900
	ITG4	360	360	540
	ITG5	900	720	900
	MEAN ± SD	675 ± 196	630 ± 156	765 ± 149

* - Subject dropped out of the study
** - Subject whose data was excluded for the statistical analysis

Table 42 - Time at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	5.5	6.0	6.5
	CG2**	5.5	5.0	4.0
	CG3	5.5	5.5	6.0
	CG4	4.0	4.5	4.5
	CG5	3.5	4.0	4.0
	MEAN ± SD	4.6 ± 0.9	5.0 ± 0.8	5.3 ± 1.0
	TG1	4.0	5.0	5.5
	TG2**	4.5	4.5	4.5
	TG3	4.5	5.5	6.0
	TG4	4.0	4.0	5.5
	TG5	4.5	5.0	5.5
HIGH	MEAN ± SD	4.3 ± 0.3	4.9 ± 0.5	5.6 ± 0.2
	ATG1	4.5	4.5	5.0
	ATG2*	4.5	--	--
	ATG3	4.5	5.0	6.0
	ATG4	5.5	6.0	6.0
	ATG5	6.0	5.5	6.5
	MEAN ± SD	5.1 ± 0.6	5.3 ± 0.6	5.9 ± 0.5
	ITG1	5.5	6.5	5.5
	ITG2**	5.5	6.0	5.5
	ITG3	7.0	8.0	7.5
	ITG4	4.5	5.0	4.5
	ITG5	4.5	4.0	6.0
	MEAN ± SD	5.4 ± 1.0	5.9 ± 1.5	5.9 ± 1.1
	CG1	4.0	4.5	4.5
	CG2**	3.5	4.0	4.0
	CG3	4.0	4.0	5.0
	CG4	5.0	4.5	5.0
	CG5	4.5	4.5	4.0
	MEAN ± SD	4.4 ± 0.4	4.4 ± 0.2	4.6 ± 0.4
	TG1	5.0	4.5	4.5
	TG2*	3.5	--	--
	TG3	5.0	5.0	5.0
	TG4	4.5	4.5	6.0
	TG5	3.5	4.5	4.5
LOW	MEAN ± SD	4.5 ± 0.6	4.6 ± 0.2	5.0 ± 0.6
	ATG1	4.5	4.5	4.5
	ATG2**	4.0	4.0	4.0
	ATG3	5.0	6.0	5.5
	ATG4	2.5	3.5	5.0
	ATG5	4.0	4.0	4.0
	MEAN ± SD	4.0 ± 0.9	4.5 ± 0.9	4.8 ± 0.6
	ITG1	4.5	5.0	5.0
	ITG2**	5.0	5.0	5.0
	ITG3	5.0	4.5	6.0
	ITG4	3.0	2.5	4.0
	ITG5	5.5	5.0	5.5
	MEAN ± SD	4.5 ± 0.9	4.3 ± 1.0	5.1 ± 0.7

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 43 - Ventilation Volume at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	42058	50095	50452
	CG2**	45199	39091	32054
	CG3	39784	38957	34748
	CG4	31356	32676	35546
	CG5	24682	29651	31113
	MEAN ± SD	34470 ± 6916	37845 ± 7829	37965 ± 7401
	TG1	32353	36675	44855
	TG2**	32353	33808	28955
	TG3	31965	37951	39707
	TG4	30205	27173	40143
	TG5	34740	30279	37017
HIGH	MEAN ± SD	32316 ± 1617	33020 ± 4455	40431± 2821
	ATG1	29964	35388	31161
	ATG2*	37860	--	--
	ATG3	29760	32900	31266
	ATG4	45619	46469	45640
	ATG5	42242	36710	40950
	MEAN ± SD	36896 ± 7135	37866 ± 5151	37254 ± 6264
	ITG1	45147	54773	45388
	ITG2**	46823	62161	47668
	ITG3	56139	66691	65090
	ITG4	34487	37958	32463
	ITG5	35273	31784	37593
	MEAN ± SD	42761 ± 8792	47801 ± 13774	45134 ± 12407
	CG1	24831	30135	28557
	CG2**	22892	22639	28610
	CG3	27087	27000	38977
	CG4	35414	34401	39091
	CG5	28350	27524	25811
	MEAN ± SD	28920 ± 3955	29765 ± 2928	33109 ± 6004
	TG1	42343	38131	33829
	TG2*	32434	--	--
	TG3	29969	27242	31728
	TG4	31136	34053	44649
	TG5	34142	41621	42119
LOW	MEAN ± SD	34398 ± 4833	35261 ± 5349	38081 ± 5429
	ATG1	28972	34388	32182
	ATG2**	33909	29289	35573
	ATG3	33723	47162	39111
	ATG4	20525	31480	40860
	ATG5	31351	31746	33320
	MEAN ± SD	28530 ± 4866	36194 ± 6434	36368 ± 3692
	ITG1	37447	39780	41091
	ITG2**	41951	38201	40351
	ITG3	33462	33373	37380
	ITG4	27301	32846	32616
	ITG5	27268	33601	32150
	MEAN ± SD	31369 ± 4321	34900 ± 2831	35809 ± 3673

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 44 - Absolute Oxygen Consumption at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	1971	1864	2023
	CG2**	1529	1616	1363
	CG3	1569	1502	1318
	CG4	1353	1430	1460
	CG5	1034	1193	1207
	MEAN ± SD	1481.8 ± 340.6	1497.3 ± 240.6	1502 ± 313.9
	TG1	1502	1521	1743
	TG2**	1408	1406	1279
	TG3	1412	1675	1772
	TG4	1071	1054	1487
	TG5	1632	1463	1807
HIGH	MEAN ± SD	1404.3 ± 207.7	1428.3 ± 229.5	1702.3 ± 126.3
	ATG1	1489	1566	1505
	ATG2 *	1623	--	--
	ATG3	1419	1272	1420
	ATG4	1829	1864	1730
	ATG5	1684	1845	1859
	MEAN ± SD	1605.3 ± 161.6	1636.8 ± 241.4	1628.5 ± 174.8
	ITG1	1984	2150	1709
	ITG2**	1423	1745	1700
	ITG3	2291	2609	2462
	ITG4	1440	1636	1437
	ITG5	1488	1481	1546
	MEAN ± SD	1800.8 ± 354.2	1969.0 ± 444.8	1788.5 ± 400.7
	CG1	961	1167	1106
	CG2**	1059	971	1152
	CG3	1088	1063	1457
	CG4	1453	1428	1616
	CG5	1177	1185	1054
	MEAN ± SD	1169.8 ± 180.7	1210.8 ± 133.8	1308.3 ± 235.8
	TG1	1504	1501	1584
	TG2*	1235	--	--
	TG3	1446	1128	1477
	TG4	1296	1335	1771
	TG5	1282	1728	1631
LOW	MEAN ± SD	1382.0 ± 95.4	1423.0 ± 220.2	1615.8 ± 105.6
	ATG1	1263	1428	1305
	ATG2**	1249	1218	1421
	ATG3	1285	1494	1428
	ATG4	742	1084	1504
	ATG5	1128	1191	1193
	MEAN ± SD	1104.5 ± 217.8	1299.3 ± 167.7	1357.5 ± 118.6
	ITG1	1505	1565	1451
	ITG2**	1607	1366	1566
	ITG3	1469	1432	1556
	ITG4	1031	1174	1378
	ITG5	1495	1587	1515
	MEAN ± SD	1375.0 ± 199.0	1439.5 ± 164.4	1475.0 ± 67.4

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 45 - Relative Oxygen Consumption at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	23.6	22.5	24.4
	CG2**	25.4	26.8	22.5
	CG3	22.0	21.3	18.5
	CG4	16.5	17.8	18.4
	CG5	15.8	18.2	18.4
	MEAN ± SD	19.5 ± 3.4	20.0 ± 2.0	19.9 ± 2.6
	TG1	18.9	19.2	22.2
	TG2**	21.6	21.9	19.8
	TG3	21.5	25.2	27.0
	TG4	18.0	17.5	24.7
	TG5	19.6	17.9	21.7
HIGH	MEAN ± SD	19.5 ± 1.3	20.0 ± 3.1	23.9 ± 2.1
	ATG1	19.2	20.6	20.0
	ATG2*	19.2	--	--
	ATG3	19.3	17.3	19.4
	ATG4	25.8	26.1	24.0
	ATG5	20.5	23.1	23.5
	MEAN ± SD	21.2 ± 2.7	21.8 ± 3.2	21.7 ± 2.0
	ITG1	30.0	32.3	25.4
	ITG2**	20.9	25.0	25.0
	ITG3	26.4	29.5	27.8
	ITG4	16.5	18.5	16.6
	ITG5	19.6	19.5	20.6
	MEAN ± SD	23.1 ± 5.3	25.0 ± 6.0	22.6 ± 4.3
	CG1	15.1	18.5	17.5
	CG2**	14.9	13.5	16.3
	CG3	13.6	13.8	19.0
	CG4	16.6	16.4	18.5
	CG5	16.7	16.5	14.9
	MEAN ± SD	15.5 ± 1.3	16.3 ± 1.7	17.5 ± 1.6
	TG1	19.1	19.3	20.3
	TG2*	16.4	--	--
	TG3	17.3	13.4	17.9
	TG4	14.4	14.8	19.7
	TG5	13.3	18.4	17.2
LOW	MEAN ± SD	16.0 ± 2.3	16.5 ± 2.4	18.8 ± 1.3
	ATG1	19.0	21.4	20.2
	ATG2**	15.4	15.3	17.3
	ATG3	18.0	21.2	20.3
	ATG4	10.0	14.3	20.1
	ATG5	14.4	15.6	15.7
	MEAN ± SD	15.4 ± 3.5	18.1 ± 3.2	19.1 ± 1.9
	ITG1	15.8	16.7	15.2
	ITG2**	19.6	16.6	19.3
	ITG3	19.6	18.8	21.3
	ITG4	11.6	13.2	15.5
	ITG5	19.7	20.8	19.9
	MEAN ± SD	16.7 ± 3.3	17.4 ± 2.8	18.0 ± 2.7

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 46 - $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One

Category	Group/Rank	Pre	Mid	Post
	CG1	21.3	26.9	24.9
	CG2**	29.6	24.2	23.5
	CG3	25.4	25.9	26.4
	CG4	23.1	22.9	24.3
	CG5	23.9	24.9	25.8
	MEAN ± SD	23.4 ± 1.5	25.2 ± 1.5	25.4 ± 0.8
	TG1	21.5	24.1	25.7
	TG2**	23.0	24.0	22.6
	TG3	22.6	22.6	22.4
	TG4	28.2	25.8	27.0
	TG5	21.3	20.7	20.5
HIGH	MEAN ± SD	23.4 ± 2.8	23.3 ± 1.9	23.9 ± 2.6
	ATG1	20.1	22.6	20.7
	ATG2*	23.3	--	--
	ATG3	21.0	25.9	22.0
	ATG4	25.0	24.9	26.4
	ATG5	25.1	19.9	22.0
	MEAN ± SD	22.8 ± 2.3	23.3 ± 2.3	22.8 ± 2.2
	ITG1	22.8	25.5	26.5
	ITG2**	32.9	35.6	28.0
	ITG3	25.7	23.1	24.0
	ITG4	24.5	25.6	26.4
	ITG5	23.9	23.2	22.6
	MEAN ± SD	23.7 ± 0.6	24.0 ± 1.7	25.0 ± 1.6
	CG1	25.8	25.8	25.8
	CG2**	21.6	23.3	24.8
	CG3	24.9	25.4	26.8
	CG4	24.4	24.1	24.2
	CG5	24.1	23.2	24.5
	MEAN ± SD	24.8 ± 0.6	24.6 ± 1.0	25.3 ± 1.0
	TG1	28.2	25.4	21.4
	TG2*	26.3	--	--
	TG3	20.7	24.2	21.5
	TG4	24.0	25.5	25.2
	TG5	26.6	24.1	25.8
LOW	MEAN ± SD	24.9 ± 2.8	24.8 ± 0.7	23.5 ± 2.0
	ATG1	23.0	24.1	24.7
	ATG2**	27.1	24.0	25.0
	ATG3	25.9	31.5	27.4
	ATG4	27.7	29.1	27.1
	ATG5	27.8	26.7	27.9
	MEAN ± SD	26.1 ± 1.9	27.9 ± 2.8	26.8 ± 1.2
	ITG1	24.9	25.4	28.3
	ITG2**	26.1	28.0	25.8
	ITG3	22.8	23.3	24.0
	ITG4	26.5	28.0	23.7
	ITG5	18.3	21.2	21.2
	MEAN ± SD	23.1 ± 3.1	24.5 ± 2.5	24.3 ± 2.6

* Subject dropped out of the study

** Subject whose data was excluded for the statistical analysis

Table 47 - Power Output at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	1620	1620	1440
	CG2**	1260	1080	1260
	CG3	1440	1620	1620
	CG4	1080	1080	900
	CG5	900	900	900
	MEAN ± SD	1260 ± 285	1305 ± 321	1215 ± 321
	TG1	1620	1620	1980
	TG2**	1080	1080	1080
	TG3	1260	1440	1440
	TG4	1080	1080	1260
	TG5	1440	1440	1440
HIGH	MEAN ± SD	1350 ± 201	1395 ± 196	1530 ± 270
	ATG1	1080	1620	1800
	ATG2*	1080	--	--
	ATG3	1440	1800	1980
	ATG4	900	1260	1620
	ATG5	1080	1260	1440
	MEAN ± SD	1125 ± 196	1485 ± 234	1710 ± 201
	ITG1	1080	1620	1620
	ITG2**	1800	1800	1980
	ITG3	1440	1620	1980
	ITG4	1260	1260	1260
	ITG5	1260	1260	1800
	MEAN ± SD	1260 ± 127	1440 ± 180	1665 ± 266
	CG1	1260	900	900
	CG2**	900	900	1080
	CG3	900	1080	1080
	CG4	1080	1080	1080
	CG5	900	900	900
	MEAN ± SD	1035 ± 149	990 ± 90	990 ± 90
	TG1	1260	1440	1440
	TG2*	1080	--	--
	TG3	1260	1620	1620
	TG4	1260	1440	1440
	TG5	720	1080	1260
LOW	MEAN ± SD	1125 ± 234	1395 ± 196	1440 ± 127
	ATG1	1260	1260	1800
	ATG2**	720	1080	1260
	ATG3	900	1260	1440
	ATG4	720	900	1080
	ATG5	720	1080	1080
	MEAN ± SD	900 ± 220	1125 ± 149	1350 ± 298
	ITG1	1260	1440	1800
	ITG2**	900	1620	1620
	ITG3	1080	1260	1620
	ITG4	1080	1260	1440
	ITG5	1260	1260	1440
	MEAN ± SD	1170 ± 90	1305 ± 77.9	1575 ± 149

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 48 - Time at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	9.5	9.5	9.0
	CG2**	8.0	6.5	8.0
	CG3	9.0	9.5	9.5
	CG4	6.5	7.0	6.0
	CG5	5.5	6.0	6.0
	MEAN ± SD	7.6 ± 1.7	8.0 ± 1.5	7.6 ± 1.6
	TG1	10.0	10.0	12.0
	TG2**	7.0	6.5	7.0
	TG3	8.0	9.0	9.0
	TG4	6.5	6.5	8.0
	TG5	8.5	8.5	9.0
HIGH	MEAN ± SD±	8.3 ± 1.3	8.5 ± 1.3	9.5 ± 1.5
	ATG1	7.0	9.5	11.0
	ATG2*	7.0	--	--
	ATG3	8.5	11.0	12.0
	ATG4	5.5	8.0	10.0
	ATG5	6.5	8.0	8.5
	MEAN ± SD	6.9 ± 1.1	9.1 ± 1.2	10.4 ± 1.3
	ITG1	6.5	9.5	9.5
	ITG2**	11.0	11.0	12.0
	ITG3	8.5	9.5	11.5
	ITG4	7.5	8.0	8.0
	ITG5	8.0	8.0	10.5
	MEAN ± SD	7.6 ± 0.7	8.8 ± 0.8	9.9 ± 1.3
	CG1	8.0	6.0	6.0
	CG2**	5.5	6.0	6.5
	CG3	6.0	6.5	7.0
	CG4	6.5	7.0	6.5
	CG5	6.0	5.5	5.5
	MEAN ± SD	6.6 ± 0.8	6.4 ± 0.7	6.3 ± 0.6
	TG1	7.5	9.0	9.0
	TG2*	7.0	--	--
	TG3	8.0	10.0	9.5
	TG4	8.0	8.5	9.0
	TG5	5.0	6.5	7.5
LOW	MEAN ± SD	7.1 ± 1.2	8.5 ± 1.3	8.8 ± 0.8
	ATG1	8.0	8.0	10.5
	ATG2**	4.5	7.0	7.5
	ATG3	5.5	7.5	9.0
	ATG4	5.0	6.0	7.0
	ATG5	5.0	7.0	7.0
	MEAN ± SD	5.9 ± 1.2	7.1 ± 0.7	8.4 ± 1.5
	ITG1	8.0	8.5	10.5
	ITG2**	6.0	10.0	9.5
	ITG3	6.5	7.5	10.0
	ITG4	6.5	8.0	8.5
	ITG5	7.5	8.0	9.0
	MEAN ± SD	7.1 ± 0.6	8.0 ± 0.4	9.5 ± 0.8

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 49 - Ventilation Volume at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	98001	97660	83530
	CG2**	71398	52307	73541
	CG3	80852	97116	93578
	CG4	51391	55974	49688
	CG5	42202	52437	53579
	MEAN ± SD	68111 ± 22397	75796 ± 21628	70093 ± 18849
	TG1	88482	89913	111055
	TG2*	59990	51797	68500
	TG3	69398	82587	81526
	TG4	54229	51236	70090
	TG5	76464	63574	62137
HIGH	MEAN ± SD	72143 ± 12390	71827 ± 15289	81202 ± 18562
	ATG1	54113	86060	95091
	ATG2*	69372	--	--
	ATG3	62704	94165	97704
	ATG4	45619	65533	93578
	ATG5	51525	65238	64067
	MEAN ± SD	53490 ± 6146	77749 ± 12692	87610 ± 13672
	ITG1	64030	90980	102278
	ITG2**	83937	132327	113609
	ITG3	76543	90410	109295
	ITG4	58121	68956	58962
	ITG5	56546	64879	77968
	MEAN ± SD	63810 ± 7863	78806 ± 11977	87126 ± 19988
	CG1	56696	39463	41393
	CG2**	35284	39905	54334
	CG3	47761	62187	63711
	CG4	48487	58044	52307
	CG5	41443	39083	34058
	MEAN ± SD	48581 ± 5422	49694 ± 10525	47867 ± 11218
	TG1	67663	80132	70145
	TG2*	82674	--	--
	TG3	56693	88635	70898
	TG4	77808	82388	90280
	TG5	55626	59441	75093
LOW	MEAN ± SD	64448 ± 9039	77649 ± 10964	76604 ± 8118
	ATG1	64134	73001	101946
	ATG2**	37809	65977	71339
	ATG3	44371	75972	71913
	ATG4	40101	63793	60820
	ATG5	40472	60380	65264
	MEAN ± SD	47269 ± 9879	68332 ± 6372	74986 ± 16058
	ITG1	71810	78791	111801
	ITG2**	54744	98210	92548
	ITG3	44035	57419	70268
	ITG4	67365	90137	98378
	ITG5	46581	60903	60969
	MEAN ± SD	57448 ± 12274	71813 ± 13329	85354 ± 20563

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 50 - Absolute Oxygen Consumption at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	3565	3159	2986
	CG2**	2326	2006	2589
	CG3	2656	2888	3089
	CG4	2083	2304	1911
	CG5	1513	1729	1691
	MEAN ± SD	2454.3 ± 758	2520.0 ± 551.4	2419.3 ± 624.2
	TG1	3363	3255	3535
	TG2**	2390	2038	2420
	TG3	2562	2931	2856
	TG4	1829	1805	2247
	TG5	2915	2732	2746
HIGH	MEAN ± SD	2667.3 ± 561.1	2680.8 ± 539.0	2846.0 ± 459.2
	ATG1	2315	3236	3272
	ATG2*	2766	--	--
	ATG3	2775	3053	3384
	ATG4	1829	2396	3035
	ATG5	1923	2607	2499
	MEAN ± SD	2210.5 ± 373.4	2823.0 ± 336.3	3047.5 ± 340.8
	ITG1	2286	3099	3000
	ITG2**	2292	3744	3537
	ITG3	2507	2831	2857
	ITG4	2896	3279	3533
	ITG5	2286	2513	2372
	MEAN ± SD	2455.3 ± 255.9	2854.3 ± 340.8	2938.3 ± 414.2
	CG1	2013	1356	1430
	CG2**	1554	1536	1789
	CG3	1681	1948	2089
	CG4	1895	2181	2006
	CG5	1582	1573	1285
	MEAN ± SD	1792.8 ± 170.2	1764.5 ± 320.4	1702.5 ± 350.0
	TG1	2117	2778	2673
	TG2*	2445	--	--
	TG3	2367	2582	2579
	TG4	2348	2639	2761
	TG5	1883	2204	2477
LOW	MEAN ± SD	2178.8 ± 197.1	2550.8 ± 212.5	2622.5 ± 105.8
	ATG1	2114	2554	3041
	ATG2**	1379	2333	2433
	ATG3	1601	2037	2445
	ATG4	1274	1905	2054
	ATG5	1394	1809	1909
	MEAN ± SD	1595.8 ± 321.3	2076.3 ± 287.5	2362.3 ± 438.2
	ITG1	2560	2665	3312
	ITG2**	2046	2869	3159
	ITG3	1887	2290	2704
	ITG4	2143	2840	2889
	ITG5	2089	2251	2321
	MEAN ± SD	2169.8 ± 244.7	2511.5 ± 249.2	2806.5 ± 356.6

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 51 - Relative Oxygen Consumption at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	42.7	38.4	36.0
	CG2**	38.6	33.6	42.8
	CG3	37.6	40.6	43.9
	CG4	25.3	28.6	24.0
	CG5	26.2	26.4	25.8
	MEAN ± SD	33.0 ± 7.4	33.5 ± 6.1	32.4 ± 8.1
	TG1	42.3	41.0	45.0
	TG2**	36.7	31.8	37.5
	TG3	38.9	44.1	43.5
	TG4	30.8	29.9	37.4
	TG5	35.1	33.5	33.0
HIGH	MEAN ± SD	36.8 ± 4.3	37.1 ± 5.7	39.8 ± 4.8
	ATG1	29.8	42.6	43.4
	ATG2*	32.7	--	--
	ATG3	37.8	41.5	46.0
	ATG4	25.8	33.5	42.0
	ATG5	23.4	32.6	31.6
	MEAN ± SD	29.2 ± 5.5	37.6 ± 4.5	40.8 ± 5.5
	ITG1	34.6	46.6	44.6
	ITG2**	33.7	53.7	52.0
	ITG3	33.4	37.1	39.9
	ITG4	26.2	28.4	27.4
	ITG5	31.0	33.3	38.0
	MEAN ± SD	31.3 ± 3.2	36.4 ± 6.7	37.5 ± 6.3
	CG1	31.6	21.5	22.6
	CG2**	21.9	21.3	25.3
	CG3	21.0	25.2	27.2
	CG4	21.7	25.0	23.0
	CG5	22.5	22.0	18.2
	MEAN ± SD	24.2 ± 4.3	23.4 ± 1.7	22.8 ± 3.2
	TG1	26.9	35.8	34.2
	TG2*	32.5	--	--
	TG3	28.3	30.8	31.2
	TG4	26.1	29.3	30.7
	TG5	19.5	23.4	26.1
LOW	MEAN ± SD	25.2 ± 3.4	29.8 ± 4.4	30.6 ± 2.9
	ATG1	31.8	38.3	47.0
	ATG2**	17.0	29.3	29.6
	ATG3	22.5	28.9	34.8
	ATG4	17.2	25.1	27.4
	ATG5	17.7	23.7	25.0
	MEAN ± SD	22.3 ± 5.9	29.0 ± 5.7	33.6 ± 8.6
	ITG1	26.8	28.5	34.8
	ITG2**	25.0	34.9	28.9
	ITG3	25.2	30.1	37.0
	ITG4	24.1	31.8	32.6
	ITG5	27.5	29.5	30.5
	MEAN ± SD	25.9 ± 1.3	30.0 ± 1.2	33.7 ± 1.4

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 52 - $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two

Category	Group/Rank	Pre	Mid	Post
	CG1	27.5	30.9	28.0
	CG2**	30.7	26.0	28.4
	CG3	30.4	33.6	30.3
	CG4	24.7	24.3	26.0
	CG5	27.9	30.3	31.7
	MEAN ± SD	27.6 ± 2.0	29.8 ± 3.4	29.0 ± 2.2
	TG1	26.3	27.6	31.4
	TG2**	25.1	25.4	28.3
	TG3	27.1	28.2	28.5
	TG4	29.6	28.4	31.2
	TG5	26.2	23.3	22.6
HIGH	MEAN ± SD	27.3 ± 1.4	26.9 ± 2.1	28.4 ± 3.6
	ATG1	23.4	26.6	29.1
	ATG2*	25.1	--	--
	ATG3	22.6	30.8	28.9
	ATG4	25.0	27.4	30.8
	ATG5	26.8	25.0	25.6
	MEAN ± SD	24.5 ± 1.6	27.5 ± 2.1	28.6 ± 1.9
	ITG1	28.0	29.4	34.1
	ITG2**	36.6	35.3	32.1
	ITG3	27.0	26.3	25.3
	ITG4	26.4	27.6	30.9
	ITG5	25.4	27.4	24.9
	MEAN ± SD	26.0 ± 1.5	27.5 ± 1.3	29.3 ± 3.5
	CG1	28.2	29.1	28.9
	CG2**	22.7	26.0	30.4
	CG3	28.4	31.9	30.5
	CG4	25.6	26.6	26.0
	CG5	26.2	24.8	26.5
	MEAN ± SD	27.1 ± 1.2	28.1 ± 2.7	28.0 ± 1.8
	TG1	31.9	28.8	26.2
	TG2*	33.8	--	--
	TG3	24.0	34.3	27.5
	TG4	33.1	31.2	32.7
	TG5	29.6	27.0	30.3
LOW	MEAN ± SD	29.7 ± 3.5	30.3 ± 2.7	29.2 ± 2.5
	ATG1	30.3	28.6	33.5
	ATG2**	27.1	28.3	29.3
	ATG3	27.7	37.3	29.4
	ATG4	31.5	33.5	29.6
	ATG5	29.0	33.4	34.2
	MEAN ± SD	29.6 ± 1.4	33.2 ± 3.1	31.7 ± 2.2
	ITG1	28.1	29.6	33.8
	ITG2**	26.8	34.2	29.3
	ITG3	23.4	25.1	26.0
	ITG4	31.4	31.8	34.1
	ITG5	22.3	27.1	26.3
	MEAN ± SD	26.3 ± 3.7	28.4 ± 2.5	30.1 ± 3.9

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 53 - Power output at Threshold One expressed as a Percentage of the Power Output at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	45.5	50.0	54.5
	CG2**	50.0	44.4	30.0
	CG3	50.0	50.0	45.5
	CG4	30.0	40.0	40.0
	CG5	37.5	33.3	33.3
	MEAN ± SD	40.8 ± 7.7	43.3 ± 7.1	43.3 ± 7.8
	TG1	27.3	33.3	41.7
	TG2**	50.0	50.0	44.4
	TG3	44.4	50.0	50.0
	TG4	37.5	37.5	50.0
	TG5	44.4	40.0	41.7
HIGH	MEAN ± SD	38.4 ± 7.0	40.2 ± 6.1	45.9 ± 4.2
	ATG1	40.0	36.4	30.8
	ATG2*	40.0	--	--
	ATG3	40.0	30.8	35.7
	ATG4	55.6	50.0	45.5
	ATG5	45.5	41.7	46.2
	MEAN ± SD	45.3 ± 6.4	39.7 ± 7.1	39.6 ± 6.5
	ITG1	55.6	60.0	45.5
	ITG2**	45.5	45.5	41.7
	ITG3	54.5	58.3	53.8
	ITG4	40.0	33.3	30.8
	ITG5	36.4	25.0	38.5
	MEAN ± SD	46.6 ± 8.5	44.2 ± 15.3	42.2 ± 8.5
	CG1	33.3	50.0	44.4
	CG2**	37.5	37.5	37.5
	CG3	30.0	30.0	40.0
	CG4	40.0	40.0	40.0
	CG5	50.0	50.0	37.5
	MEAN ± SD	38.3 ± 7.6	42.5 ± 8.3	40.5 ± 2.5
	TG1	40.0	36.4	33.3
	TG2*	37.5	--	--
	TG3	44.4	36.4	33.3
	TG4	44.4	40.0	50.0
	TG5	37.5	44.4	40.0
LOW	MEAN ± SD	41.6 ± 3.0	39.3 ± 3.3	39.2 ± 6.8
	ATG1	44.4	40.0	36.4
	ATG2**	33.3	30.0	27.3
	ATG3	44.4	50.0	41.7
	ATG4	25.0	33.3	27.3
	ATG5	50.0	44.4	40.0
	MEAN ± SD	37.8 ± 7.9	39.2 ± 6.8	35.5 ± 5.2
	ITG1	36.4	30.8	30.8
	ITG2**	44.4	36.4	33.3
	ITG3	44.4	33.3	38.5
	ITG4	25.0	22.2	30.0
	ITG5	55.6	40.0	41.7
	MEAN ± SD	40.4 ± 11.2	31.6 ± 6.4	35.3 ± 5.0

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 54 - Time at Threshold One expressed as a Percentage of the Time at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	47.8	54.5	56.5
	CG2**	52.4	50.0	38.1
	CG3	52.4	52.4	52.2
	CG4	38.1	38.1	42.9
	CG5	38.9	42.1	42.1
	MEAN ± SD	44.3 ± 6.0	46.8 ± 6.9	48.4 ± 6.1
	TG1	34.8	40.0	42.3
	TG2**	50.0	50.0	47.4
	TG3	47.4	52.4	57.1
	TG4	44.4	44.4	50.0
	TG5	47.4	45.5	42.3
HIGH	MEAN ± SD	43.5 ± 5.2	45.6 ± 4.4	47.9 ± 6.2
	ATG1	42.9	39.1	37.0
	ATG2*	40.9	--	--
	ATG3	42.9	37.0	41.4
	ATG4	57.9	57.1	52.2
	ATG5	52.2	44.0	48.1
	MEAN ± SD	49.0 ± 6.4	44.3 ± 7.8	44.7 ± 5.9
	ITG1	55.0	59.1	47.8
	ITG2**	45.8	50.0	42.3
	ITG3	58.3	61.5	55.6
	ITG4	40.1	38.5	32.1
	ITG5	39.1	30.8	42.9
	MEAN ± SD	48.1 ± 8.6	47.5 ± 13.1	44.6 ± 8.5
	CG1	42.1	50.0	47.4
	CG2**	38.9	38.9	47.1
	CG3	38.1	38.1	47.6
	CG4	47.6	42.9	47.6
	CG5	52.9	50.0	44.4
	MEAN ± SD	45.2 ± 5.6	45.3 ± 5.0	46.8 ± 1.4
	TG1	47.6	39.1	34.6
	TG2*	38.9	--	--
	TG3	50.0	41.7	40.0
	TG4	47.4	42.9	57.1
	TG5	41.2	45.0	42.9
LOW	MEAN ± SD	46.6 ± 3.3	42.2 ± 2.1	43.7 ± 8.3
	ATG1	45.0	42.9	39.1
	ATG2**	42.1	38.1	34.8
	ATG3	50.0	57.1	44.0
	ATG4	27.8	35.0	41.0
	ATG5	44.4	42.1	34.8
	MEAN ± SD	41.8 ± 8.4	44.3 ± 8.0	39.9 ± 3.4
	ITG1	39.1	35.7	35.7
	ITG2**	52.6	43.5	38.5
	ITG3	50.0	34.6	42.9
	ITG4	35.3	25.0	36.4
	ITG5	57.9	45.5	44.0
	MEAN ± SD	45.6 ± 8.9	35.2 ± 7.3	39.8 ± 3.7

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 55 - Ventilation Volume at Threshold One expressed as a Percentage of the Ventilation Volume at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	25.0	33.1	35.5
	CG2**	38.0	36.2	27.2
	CG3	32.5	36.2	24.7
	CG4	23.1	26.7	27.2
	CG5	22.0	23.9	25.6
	MEAN ± SD	25.7 ± 4.1	28.6 ± 3.6	28.3 ± 4.3
	TG1	25.4	25.1	31.1
	TG2**	24.3	28.2	31.1
	TG3	32.0	23.6	28.2
	TG4	24.9	23.2	29.1
	TG5	30.0	23.6	28.0
HIGH	MEAN ± SD	28.1 ± 3.0	23.9 ± 0.7	29.1 ± 1.2
	ATG1	23.2	25.4	19.5
	ATG2*	21.9	--	--
	ATG3	29.2	22.2	21.7
	ATG4	44.6	39.6	35.6
	ATG5	26.3	21.3	24.6
	MEAN ± SD	30.8 ± 8.2	27.1 ± 7.4	25.4 ± 6.2
	ITG1	34.7	38.7	25.4
	ITG2**	27.2	35.5	31.8
	ITG3	36.1	41.6	38.1
	ITG4	24.0	22.1	22.3
	ITG5	30.7	26.8	31.0
	MEAN ± SD	31.4 ± 4.7	32.3 ± 8.1	29.2 ± 6.0
	CG1	22.9	28.8	23.7
	CG2**	19.7	17.8	26.8
	CG3	20.0	16.6	30.3
	CG4	26.1	26.7	29.8
	CG5	39.2	28.9	27.1
	MEAN ± SD	27.1 ± 7.3	25.3 ± 5.1	27.7 ± 2.6
	TG1	28.8	28.2	22.9
	TG2*	22.6	--	--
	TG3	32.1	21.2	22.7
	TG4	28.5	25.3	32.4
	TG5	27.9	24.1	27.7
LOW	MEAN ± SD	29.3 ± 1.6	24.7 ± 2.5	26.4 ± 40
	ATG1	23.0	26.6	19.3
	ATG2**	22.4	17.8	21.1
	ATG3	23.6	29.2	26.0
	ATG4	17.4	20.5	26.7
	ATG5	26.6	27.6	21.9
	MEAN ± SD	22.7 ± 3.3	26.0 ± 3.3	23.5 ± 3.0
	ITG1	24.4	23.5	22.5
	ITG2**	28.7	24.2	23.6
	ITG3	41.6	25.0	29.0
	ITG4	21.8	23.9	21.5
	ITG5	40.7	30.5	29.0
	MEAN ± SD	32.1 ± 9.1	25.7 ± 2.8	25.5 ± 3.5

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 56 - Oxygen Consumption at Threshold One expressed as a Percentage of the Oxygen Consumption at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	45.8	46.5	53.2
	CG2**	51.1	51.7	43.1
	CG3	46.9	44.8	37.1
	CG4	36.4	36.3	40.3
	CG5	37.0	41.8	41.8
	MEAN ± SD	41.5 ± 4.8	42.4 ± 3.9	43.1 ± 6.1
	TG1	38.0	37.3	45.2
	TG2**	45.6	45.5	38.9
	TG3	45.5	47.0	51.5
	TG4	42.4	39.3	51.3
	TG5	46.7	37.8	46.7
HIGH	MEAN ± SD	43.2 ± 3.4	40.4 ± 3.9	48.7 ± 2.8
	ATG1	38.8	38.2	37.2
	ATG2*	40.4	--	--
	ATG3	42.4	34.5	37.4
	ATG4	58.3	56.5	50.8
	ATG5	48.4	46.9	46.3
	MEAN ± SD	47.0 ± 7.4	44.0 ± 8.5	43.0 ± 5.9
	ITG1	52.1	59.5	44.8
	ITG2**	42.1	43.1	42.5
	ITG3	59.0	57.8	55.3
	ITG4	38.3	42.6	37.5
	ITG5	46.6	40.2	41.8
	MEAN ± SD	49.0 ± 7.6	50.0 ± 8.7	44.9 ± 6.6
	CG1	37.9	43.9	42.1
	CG2**	38.2	34.0	44.2
	CG3	37.1	34.4	45.0
	CG4	47.8	46.0	52.3
	CG5	53.3	55.4	51.4
	MEAN ± SD	44.0 ± 6.8	44.9 ± 7.5	47.7 ± 4.3
	TG1	46.1	40.4	41.2
	TG2	42.0	--	--
	TG3	48.6	35.1	40.2
	TG4	47.2	39.8	51.7
	TG5	45.6	50.0	46.6
LOW	MEAN ± SD	46.9 ± 1.2	41.3 ± 5.4	44.9 ± 4.6
	ATG1	47.7	44.5	38.9
	ATG2**	42.1	35.0	38.2
	ATG3	51.5	48.5	45.0
	ATG4	29.6	36.8	45.0
	ATG5	43.7	48.6	38.2
	MEAN ± SD	43.1 ± 8.3	44.6 ± 4.8	41.8 ± 3.2
	ITG1	37.5	40.9	35.1
	ITG2**	49.4	42.1	40.2
	ITG3	54.1	37.0	42.0
	ITG4	34.4	31.8	36.4
	ITG5	60.3	52.1	49.8
	MEAN ± SD	46.6 ± 10.9	40.5 ± 7.5	40.8 ± 5.8

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 57 - $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One expressed as a Percentage of the $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	54.3	71.2	66.6
	CG2**	74.4	70.1	63.0
	CG3	69.6	68.7	66.7
	CG4	63.3	73.6	67.5
	CG5	59.6	57.4	61.4
	MEAN ± SD	61.7 ± 5.6	67.7 ± 6.2	65.6 ± 2.4
	TG1	66.6	67.3	68.7
	TG2**	53.5	57.0	49.5
	TG3	70.2	50.0	54.8
	TG4	58.8	59.0	56.8
	TG5	64.4	62.7	59.9
HIGH	MEAN ± SD	65.0 ± 4.1	59.8 ± 6.4	60.1 ± 5.3
	ATG1	59.8	66.7	52.3
	ATG2*	56.7	--	--
	ATG3	72.9	64.6	57.7
	ATG4	76.7	69.9	70.0
	ATG5	54.4	45.3	53.1
	MEAN ± SD	66.0 ± 9.2	61.6 ± 9.6	58.3 ± 7.1
	ITG1	66.7	65.1	56.6
	ITG2**	64.6	82.4	74.7
	ITG3	61.1	72.1	68.8
	ITG4	62.6	57.9	59.2
	ITG5	65.8	66.8	74.1
	MEAN ± SD	64.1 ± 2.3	64.0 ± 7.4	64.7 ± 7.1
	CG1	60.4	65.3	56.1
	CG2**	51.6	52.5	60.6
	CG3	53.8	48.3	67.3
	CG4	54.7	58.1	56.9
	CG5	73.7	52.1	52.9
	MEAN ± SD	60.7 ± 7.9	56.0 ± 6.4	58.3 ± 5.4
	TG1	62.5	63.6	55.7
	TG2*	53.9	--	--
	TG3	66.1	60.5	48.3
	TG4	60.3	63.3	62.5
	TG5	61.4	48.3	59.5
LOW	MEAN ± SD	62.6 ± 2.2	58.9 ± 6.3	56.5 ± 5.3
	ATG1	48.4	59.8	49.7
	ATG2**	53.2	50.8	55.3
	ATG3	45.8	60.1	57.8
	ATG4	58.7	75.0	59.2
	ATG5	60.8	56.9	57.4
	MEAN ± SD	53.4 ± 6.4	63.0 ± 7.1	56.0 ± 3.7
	ITG1	64.8	57.3	64.0
	ITG2**	58.0	57.4	58.8
	ITG3	76.8	67.5	69.0
	ITG4	63.4	75.1	59.0
	ITG5	67.8	58.6	58.2
	MEAN ± SD	68.2 ± 5.2	64.6 ± 7.2	62.6 ± 4.3

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 58 - Power Output at Threshold Two expressed as a Percentage of the Power Output at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	81.8	90.0	72.7
	CG2**	70.0	66.7	70.0
	CG3	80.0	90.0	81.8
	CG4	60.0	60.0	50.0
	CG5	62.5	55.6	55.6
	MEAN ± SD	71.1 ± 9.9	73.9 ± 16.2	65.0 ± 12.8
	TG1	81.8	75.0	91.7
	TG2**	75.0	75.0	66.7
	TG3	77.8	80.0	80.0
	TG4	75.0	75.0	70.0
	TG5	88.9	80.0	66.7
HIGH	MEAN ± SD	80.9 ± 5.2	77.5 ± 2.5	77.1 ± 9.7
	ATG1	60.0	81.8	76.9
	ATG2*	60.0	--	--
	ATG3	80.0	76.9	78.6
	ATG4	55.6	70.0	81.8
	ATG5	54.5	58.3	61.5
	MEAN ± SD	62.5 ± 10.3	71.8 ± 8.8	74.7 ± 7.8
	ITG1	66.7	90.0	81.8
	ITG2**	90.9	90.9	91.7
	ITG3	72.7	75.0	84.6
	ITG4	70.0	58.3	53.8
	ITG5	63.6	58.3	76.9
	MEAN ± SD	68.3 ± 3.4	70.4 ± 13.2	74.3 ± 12.1
	CG1	77.8	62.5	55.6
	CG2**	62.5	62.5	75.0
	CG3	50.0	60.0	60.0
	CG4	60.0	60.0	60.0
	CG5	62.5	62.5	62.5
	MEAN ± SD	62.6 ± 10.0	61.3 ± 1.3	39.5 ± 2.5
	TG1	70.0	72.7	66.7
	TG2*	75.0	--	--
	TG3	77.8	81.8	75.0
	TG4	77.8	80.0	80.0
	TG5	50.0	66.7	70.0
LOW	MEAN ± SD	68.9 ± 11.4	75.3 ± 6.0	72.9 ± 5.0
	ATG1	77.8	70.0	90.9
	ATG2**	44.4	60.0	63.6
	ATG3	55.6	70.0	66.7
	ATG4	50.0	55.6	54.5
	ATG5	50.0	66.7	54.5
	MEAN ± SD	58.4 ± 11.5	65.6 ± 5.9	66.7 ± 14.9
	ITG1	63.6	61.5	76.9
	ITG2**	55.6	81.8	75.0
	ITG3	66.7	58.3	69.2
	ITG4	75.0	77.8	80.0
	ITG5	77.8	70.0	66.7
	MEAN ± SD	70.8 ± 5.8	66.9 ± 7.6	73.2 ± 5.4

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 59 - Time at Threshold Two expressed as a Percentage of the Time at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	82.6	86.4	78.3
	CG2**	76.2	65.0	76.2
	CG3	85.7	90.5	82.6
	CG4	61.9	66.7	57.1
	CG5	61.1	63.2	63.2
	MEAN ± SD	72.8 ± 11.4	76.7 ± 11.9	70.3 ± 10.5
	TG1	87.0	80.0	92.3
	TG2**	77.8	72.2	73.7
	TG3	84.2	85.7	85.7
	TG4	72.2	72.2	69.2
	TG5	89.5	77.3	69.2
HIGH	MEAN ± SD	83.2 ± 6.6	78.8 ± 4.9	80.0 ± 9.4
	ATG1	66.7	82.6	81.5
	ATG2*	63.6	--	--
	ATG3	80.9	82.7	82.8
	ATG4	57.9	76.2	87.0
	ATG5	56.5	64.0	63.0
	MEAN ± SD	65.5 ± 9.7	76.4 ± 7.6	78.6 ± 9.2
	ITG1	65.0	86.4	82.6
	ITG2**	91.7	91.7	92.3
	ITG3	70.8	73.1	85.2
	ITG4	68.2	61.5	57.1
	ITG5	69.6	61.5	75.0
	MEAN ± SD	68.4 ± 2.2	70.6 ± 10.3	75.0 ± 11.0
	CG1	84.2	66.7	63.2
	CG2**	61.1	66.7	76.5
	CG3	57.1	61.9	66.7
	CG4	61.9	66.7	61.9
	CG5	70.6	61.1	61.1
	MEAN ± SD	68.5 ± 10.3	64.1 ± 2.6	63.2 ± 2.1
	TG1	71.4	78.3	69.2
	TG2*	77.8	--	--
	TG3	80.0	83.3	76.0
	TG4	84.2	81.0	85.7
	TG5	58.8	65.0	71.4
LOW	MEAN ± SD	73.6 ± 9.7	76.9 ± 7.1	75.6 ± 6.3
	ATG1	80.0	76.2	91.3
	ATG2**	47.4	66.7	65.2
	ATG3	55.0	71.4	72.0
	ATG4	55.6	60.0	58.3
	ATG5	55.6	73.7	60.9
	MEAN ± SD	61.6 ± 10.7	70.3 ± 6.2	70.6 ± 13.0
	ITG1	69.6	60.7	75.0
	ITG2**	63.2	86.9	73.1
	ITG3	65.1	57.7	71.4
	ITG4	76.5	80.0	77.3
	ITG5	78.9	72.7	72.0
	MEAN ± SD	72.5 ± 5.5	67.8 ± 9.0	73.9 ± 2.4

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 60 - Ventilation Volume at Threshold Two expressed as a Percentage of the Ventilation Volume at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	58.2	64.5	58.7
	CG2**	60.0	48.5	62.4
	CG3	66.2	76.7	66.5
	CG4	38.0	45.7	38.1
	CG5	37.7	42.3	44.2
	MEAN ± SD	50.0 ± 12.5	57.3 ± 14.0	51.9 ± 11.3
	TG1	69.5	61.5	77.1
	TG2**	45.1	39.8	45.4
	TG3	69.4	51.2	57.9
	TG4	44.7	43.7	50.9
	TG5	66.0	49.7	47.0
HIGH	MEAN ± SD	62.4 ± 10.3	51.5 ± 6.4	58.2 ± 11.6
	ATG1	42.0	61.8	59.5
	ATG2*	40.0	--	--
	ATG3	61.6	63.4	67.7
	ATG4	44.6	55.8	72.9
	ATG5	32.1	37.8	38.5
	MEAN ± SD	45.1 ± 10.6	54.7 ± 10.2	59.7 ± 13.1
	ITG1	49.2	64.3	57.3
	ITG2**	48.7	75.5	75.7
	ITG3	57.9	48.3	48.6
	ITG4	49.2	56.4	64.0
	ITG5	40.5	40.2	40.2
	MEAN ± SD	47.0 ± 3.8	53.9 ± 8.7	56.5 ± 9.8
	CG1	52.4	37.6	34.3
	CG2**	30.4	31.4	50.9
	CG3	35.2	38.2	49.5
	CG4	35.7	45.0	39.8
	CG5	57.4	41.1	35.8
	MEAN ± SD	45.2 ± 9.9	40.5 ± 2.9	39.9 ± 5.9
	TG1	46.0	59.3	47.6
	TG2*	57.6	--	--
	TG3	60.7	69.1	50.6
	TG4	71.1	61.2	65.4
	TG5	45.5	34.5	49.5
LOW	MEAN ± SD	55.8 ± 10.7	56.0 ± 13.0	53.3 ± 7.1
	ATG1	50.9	56.6	61.2
	ATG2**	25.0	40.2	42.4
	ATG3	31.5	47.1	47.8
	ATG4	33.9	41.5	39.8
	ATG5	34.4	52.4	43.0
	MEAN ± SD	37.7 ± 7.7	49.4 ± 5.7	47.8 ± 8.2
	ITG1	46.7	46.5	61.1
	ITG2**	37.5	62.1	54.1
	ITG3	54.7	43.0	54.5
	ITG4	53.9	65.5	64.7
	ITG5	69.6	55.2	55.0
	MEAN ± SD	56.2 ± 8.3	52.0 ± 8.7	58.8 ± 4.3

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 61 - Oxygen Consumption at Threshold Two expressed as a Percentage of the Oxygen Consumption at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	82.9	78.9	78.6
	CG2**	77.7	64.2	81.9
	CG3	79.5	86.1	86.9
	CG4	56.0	58.5	52.7
	CG5	54.1	60.6	58.5
	MEAN ± SD	68.1 ± 13.1	71.0 ± 11.8	69.2 ± 14.0
	TG1	85.2	79.8	91.7
	TG2**	77.3	65.9	73.4
	TG3	82.5	82.3	83.0
	TG4	72.4	67.2	77.5
	TG5	83.3	70.5	71.0
HIGH	MEAN ± SD	80.9 ± 5.0	75.0 ± 6.3	80.8 ± 7.6
	ATG1	60.3	78.9	81.0
	ATG2*	68.9	--	--
	ATG3	83.0	82.7	89.2
	ATG4	58.3	72.6	89.2
	ATG5	55.2	66.3	62.2
	MEAN ± SD	64.2 ± 11.0	75.1 ± 6.2	80.4 ± 11.0
	ITG1	60.1	85.7	78.7
	ITG2**	67.8	92.4	88.3
	ITG3	74.6	72.6	79.4
	ITG4	60.8	65.5	61.8
	ITG5	73.6	68.5	77.0
	MEAN ± SD	67.3 ± 6.8	73.1 ± 7.7	74.2 ± 7.2
	CG1	79.3	51.0	54.5
	CG2**	56.1	53.7	68.6
	CG3	57.4	63.0	64.6
	CG4	62.3	70.2	65.0
	CG5	71.6	73.5	62.6
	MEAN ± SD	67.7 ± 8.4	64.4 ± 8.6	61.7 ± 4.2
	TG1	64.9	74.9	69.6
	TG2*	83.1	--	--
	TG3	79.3	80.4	70.1
	TG4	85.5	78.9	80.7
	TG5	66.8	63.8	70.8
LOW	MEAN ± SD	74.1 ± 8.6	74.5 ± 6.5	72.8 ± 4.6
	ATG1	79.8	79.7	90.7
	ATG2**	46.4	67.1	65.4
	ATG3	64.2	66.1	77.0
	ATG4	50.9	64.7	61.5
	ATG5	54.1	73.8	61.1
	MEAN ± SD	62.3 ± 11.3	71.1 ± 6.1	72.6 ± 12.3
	ITG1	63.9	69.7	80.1
	ITG2**	63.0	88.5	81.0
	ITG3	69.5	59.2	73.0
	ITG4	71.6	76.8	76.3
	ITG5	84.3	73.9	76.3
	MEAN ± SD	72.3 ± 7.5	69.9 ± 6.7	76.4 ± 6.3

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 62 - $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two expressed as a Percentage of the $\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity

Category	Group/Rank	Pre	Mid	Post
	CG1	70.2	81.7	74.9
	CG2**	77.1	75.4	76.1
	CG3	83.3	89.1	76.5
	CG4	67.7	78.1	72.2
	CG5	69.6	69.8	75.5
	MEAN ± SD	72.7 ± 6.2	79.7 ± 6.9	74.8 ± 1.6
	TG1	81.4	77.1	83.9
	TG2**	58.4	60.3	61.9
	TG3	84.2	62.4	69.7
	TG4	61.7	65.0	65.7
	TG5	79.2	70.6	64.6
HIGH	MEAN ± SD	76.6 ± 8.8	68.8 ± 5.6	71.0 ± 7.7
	ATG1	69.6	78.5	73.5
	ATG2*	61.1	-	-
	ATG3	78.5	76.8	75.8
	ATG4	76.7	77.0	81.7
	ATG5	58.1	56.9	61.8
	MEAN ± SD	70.7 ± 8.0	72.3 ± 8.9	73.2 ± 7.2
	ITG1	81.9	75.0	72.9
	ITG2**	71.9	81.7	85.6
	ITG3	65.8	77.7	80.5
	ITG4	66.5	61.3	65.2
	ITG5	66.7	79.8	83.5
	MEAN ± SD	70.2 ± 6.7	73.5 ± 7.2	75.5 ± 7.1
	CG1	66.0	73.7	62.8
	CG2**	54.2	58.6	74.3
	CG3	61.3	60.6	76.6
	CG4	57.4	64.1	61.2
	CG5	80.1	55.7	57.2
	MEAN ± SD	66.2 ± 8.6	63.5 ± 6.6	64.5 ± 7.3
	TG1	70.7	72.2	68.2
	TG2*	75.4	-	-
	TG3	76.7	85.8	61.8
	TG4	83.2	77.0	81.1
	TG5	68.4	54.1	69.8
LOW	MEAN ± SD	74.8 ± 5.7	72.4 ± 11.6	70.2 ± 7.0
	ATG1	63.8	71.0	67.4
	ATG2**	53.2	60.0	64.8
	ATG3	49.0	71.2	62.0
	ATG4	66.7	86.3	64.6
	ATG5	63.5	71.2	85.1
	MEAN ± SD	60.8 ± 6.9	74.9 ± 6.6	69.8 ± 9.1
	ITG1	73.2	66.8	76.5
	ITG2**	60.0	70.1	66.9
	ITG3	78.8	72.8	74.7
	ITG4	75.1	85.3	84.8
	ITG5	82.6	74.9	72.7
	MEAN ± SD	77.4 ± 3.6	75.0 ± 6.7	77.2 ± 4.6

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 63 - Ventilation Volume at the Pre Training Maximum Exercise Capacity Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	168375	151510	142226
	CG2**	118967	125440	117945
	CG3	122140	126597	121119
	CG4	135655	122530	130445
	CG5	111959	110659	104912
	MEAN ± SD	134532 ± 21270	127824 ± 14876	124616 ± 13643
	TG1	127308	120351	108949
	TG2**	132870	130255	134819
	TG3	100044	95246	90141
	TG4	121296	117296	88502
	TG5	115842	78384	59262
HIGH	MEAN ± SD	116122 ± 10130	102819 ± 17112±	86714 ± 17769
	ATG1	128957	110020	90744
	ATG2*	173220	--	--
	ATG3	96229	93932	75856
	ATG4	102332	87973	87267
	ATG5	160615	145394	118853
	MEAN ± SD	122033 ± 25448	109330 ± 22329	93180 ± 15812
	ITG1	130202	102718	115577
	ITG2**	172255	175222	113609
	ITG3	116967	124967	125535
	ITG4	155514	134424	121080
	ITG5	143515	139927	103184
	MEAN ± SD	136076 ± 15073	121101 ± 16274	108135 ± 11020
	CG1	108276	127617	120644
	CG2**	116079	126994	106765
	CG3	135626	162609	128632
	CG4	135632	129050	131278
	CG5	72250	79967	89482
	MEAN ± SD	112946 ± 26014	124811 ± 29434	117509 ± 16648
	TG1	146981	111602	87699
	TG2*	143653	--	--
	TG3	93426	88635	84639
	TG4	109435	106272	102875
	TG5	122320	104457	90425
LOW	MEAN ± SD	118040 ± 19595	102742 ± 8557	91410 ± 6929
	ATG1	125921	104434	92232
	ATG2**	151364	131735	115749
	ATG3	141072	140668	102555
	ATG4	118148	128936	93043
	ATG5	117806	101252	97456
	MEAN ± SD	125737 ± 9430	118823 ± 16547	96322 ± 4111
	ITG1	153678	138455	141237
	ITG2**	146140	101309	92548
	ITG3	80509	80366	70268
	ITG4	125019	100383	69053
	ITG5	66961	86101	65201
	MEAN ± SD	100542 ± 34668	101326 ± 22642	86440 ± 31692

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 64 - Absolute Oxygen Consumption at the Pre Training Maximum Exercise Capacity Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	4300	4005	3801
	CG2**	2992	3068	3163
	CG3	3342	3355	3279
	CG4	3717	3936	3625
	CG5	2795	2699	2656
	MEAN ± SD	3538.5 ± 548.4	3498.8 ± 526.2	3340.3 ± 437.4
	TG1	3948	3795	3373
	TG2**	3090	3093	3119
	TG3	3104	3081	2921
	TG4	2526	2685	2553
	TG5	3498	3036	2505
HIGH	MEAN ± SD	3269.0 ± 522.7	3149.3 ± 403.1	2838.0 ± 348.3
	ATG1	3838	3779	3226
	ATG2*	4015	--	--
	ATG3	3343	3008	2799
	ATG4	3135	2910	2910
	ATG5	3482	3893	3494
	MEAN ± SD	3449.5 ± 256.0	3397.5 ± 441.7	3107.3 ± 272.8
	ITG1	3805	3254	3302
	ITG2**	3381	4052	3537
	ITG3	3881	4140	3717
	ITG4	3761	3617	3262
	ITG5	3196	3444	3170
	MEAN ± SD	3660.8 ± 271.7	3613.8 ± 329.8	3362.8 ± 210.1
	CG1	2537	2516	2626
	CG2**	2770	2859	2609
	CG3	2931	3090	3236
	CG4	3040	3106	3088
	CG5	2208	2056	1970
	MEAN ± SD	2679.0 ± 330.1	2692.0 ± 437.4	2730.0 ± 493.1
	TG1	3262	3559	3107
	TG2*	2943	--	--
	TG3	2984	2582	2946
	TG4	2745	2881	3021
	TG5	2820	2889	2818
LOW	MEAN ± SD	2952.8 ± 198.4	2977.8 ± 357.7	2973.0 ± 106.1
	ATG1	2649	3038	2783
	ATG2**	2970	3276	3257
	ATG3	2494	2989	2784
	ATG4	2503	2794	2677
	ATG5	2579	2240	2400
	MEAN ± SD	2556.3 ± 62.9	2765.3 ± 316.7	2661.0 ± 156.8
	ITG1	4008	3441	3621
	ITG2**	3250	2872	3159
	ITG3	2716	2847	2704
	ITG4	2995	3120	2398
	ITG5	2477	2691	2308
	MEAN ± SD	3049.0 ± 583.2	3024.8 ± 285.2	2757.8 ± 519.6

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 65 - Carbon Dioxide Production at the Pre Training Maximum Exercise Capacity Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	5203	4966	4828
	CG2**	3560	3559	3701
	CG3	4278	4362	4132
	CG4	4572	4959	4640
	CG5	3298	3347	3373
	MEAN ± SD	4337.8 ± 681.2	4408.5 ± 623.4	4243.3 ± 599.2
	TG1	5013	4592	4183
	TG2**	4079	4021	3868
	TG3	3476	3512	3271
	TG4	3208	3410	3140
	TG5	4163	3674	3131
HIGH	MEAN ± SD	3965.0 ± 710.7	3797.0 ± 498.6	3431.3 ± 402.7
	ATG1	4337	4157	3709
	ATG2*	5190	--	--
	ATG3	3878	3549	3303
	ATG4	3950	3463	3230
	ATG5	4213	4282	3878
	MEAN ± SD	4094.5 ± 575.6	3862.8 ± 396.9	3530.0 ± 299.2
	ITG1	4947	3937	4159
	ITG2**	4091	4498	4032
	ITG3	4851	4927	4386
	ITG4	4363	4015	3686
	ITG5	3579	3719	3424
	MEAN ± SD	4435.0 ± 452.7	4149.5 ± 523.1	3913.8 ± 377.7
	CG1	3069	3170	3256
	CG2**	3186	3288	3157
	CG3	3194	3430	3494
	CG4	3678	3665	3705
	CG5	2583	2570	2483
	MEAN ± SD	3131.0 ± 301.1	3208.8 ± 363.8	3234.5 ± 499.9
	TG1	3979	3951	3759
	TG2*	4107	--	--
	TG3	3521	3047	3299
	TG4	3651	3630	3474
	TG5	3581	3467	3353
LOW	MEAN ± SD	3683.0 ± 367.9	3523.8 ± 420.1	3471.8 ± 201.4
	ATG1	3550	3828	3312
	ATG2**	3623	3734	3647
	ATG3	2818	3258	2812
	ATG4	2904	3241	2998
	ATG5	3017	2598	2760
	MEAN ± SD	3072.3 ± 183.7	3231.3 ± 488.6	2970.5 ± 302.8
	ITG1	5330	4336	4454
	ITG2**	4192	3618	4043
	ITG3	3286	3388	3190
	ITG4	3773	3962	3045
	ITG5	2823	2960	2585
	MEAN ± SD	3803.0 ± 723.9	3661.5 ± 501.5	3318.5 ± 741.1

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 66 - $\dot{V}_E/\dot{V}O_2$ Ratio at the Pre Training Maximum Exercise Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	39.2	37.8	37.4
	CG2**	39.8	40.9	37.3
	CG3	36.6	37.7	36.9
	CG4	36.5	31.1	36.0
	CG5	40.1	41.0	39.5
	MEAN ± SD	38.1 ± 2.5	36.9 ± 3.6	37.5 ± 1.3
	TG1	32.3	31.7	32.3
	TG2**	43.0	42.1	43.2
	TG3	32.2	30.9	30.9
	TG4	48.0	43.7	34.6
	TG5	33.1	25.8	23.7
HIGH	MEAN ± SD	36.4 ± 6.7	33.0 ± 6.6	30.4 ± 4.1
	ATG1	33.6	29.1	28.1
	ATG2*	43.1	-	-
	ATG3	28.8	31.2	27.1
	ATG4	32.6	30.2	30.0
	ATG5	46.1	37.4	34.0
	MEAN ± SD	35.2 ± 6.5	32.0 ± 3.2	29.8 ± 2.6
	ITG1	34.2	31.6	35.0
	ITG2**	50.9	43.2	32.1
	ITG3	40.1	32.5	32.6
	ITG4	38.2	38.7	31.6
	ITG5	36.0	31.2	29.2
	MEAN ± SD	37.1 ± 2.2	33.5 ± 3.0	32.1 ± 2.1
	CG1	42.7	50.7	45.9
	CG2**	41.9	44.4	40.9
	CG3	46.3	52.6	39.8
	CG4	44.6	41.5	42.5
	CG5	32.7	38.9	45.4
	MEAN ± SD	41.6 ± 5.3	45.9 ± 5.8	43.4 ± 2.5
	TG1	45.1	31.4	28.2
	TG2*	48.8	-	-
	TG3	31.3	34.3	28.7
	TG4	39.8	36.9	34.1
	TG5	43.3	36.2	32.1
LOW	MEAN ± SD	39.9 ± 5.3	34.7 ± 2.1	30.8 ± 2.4
	ATG1	47.5	34.4	33.1
	ATG2**	50.9	40.2	35.5
	ATG3	56.5	47.1	36.8
	ATG4	47.2	46.2	34.8
	ATG5	45.7	45.2	40.6
	MEAN ± SD	49.2 ± 4.3	43.2 ± 5.1	36.3 ± 2.8
	ITG1	38.4	40.3	39.0
	ITG2**	45.0	35.3	29.3
	ITG3	29.7	28.2	26.0
	ITG4	41.8	32.2	28.8
	ITG5	27.0	32.0	28.2
	MEAN ± SD	34.2 ± 6.1	33.2 ± 4.4	30.5 ± 5.0

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 67 - $\dot{V}_E/\dot{V}CO_2$ Ratio at the Pre Training Maximum Exercise Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	32.4	30.5	29.5
	CG2**	33.4	35.2	31.9
	CG3	28.6	29.0	29.3
	CG4	29.7	24.7	28.1
	CG5	33.9	33.1	31.1
	MEAN ± SD	31.2 ± 2.7	29.3 ± 4.2	29.5 ± 2.2
	TG1	25.4	26.2	26.0
	TG2**	32.6	32.4	34.9
	TG3	28.8	27.9	27.5
	TG4	37.8	34.4	28.2
	TG5	27.8	21.3	18.9
HIGH	MEAN ± SD	29.9 ± 4.6	27.4 ± 5.1	25.1 ± 6.1
	ATG1	29.7	26.5	24.5
	ATG2*	33.4	-	-
	ATG3	24.8	26.5	23.0
	ATG4	25.9	25.4	27.0
	ATG5	38.1	34.0	30.6
	MEAN ± SD	29.6 ± 5.2	28.1 ± 4.9	26.3 ± 4.1
	ITG1	26.3	26.1	27.8
	ITG2**	42.1	39.0	28.2
	ITG3	32.1	27.3	27.6
	ITG4	32.9	34.9	28.0
	ITG5	32.2	28.9	27.1
	MEAN ± SD	30.9 ± 4.2	29.3 ± 4.7	27.6 ± 0.3
	CG1	35.3	40.3	37.1
	CG2**	36.4	38.6	33.8
	CG3	42.5	47.4	36.8
	CG4	36.9	35.2	35.4
	CG5	28.0	31.1	36.0
	MEAN ± SD	35.7 ± 5.4	38.5 ± 6.6	36.3 ± 0.5
	TG1	36.9	28.2	23.3
	TG2*	35.0	-	-
	TG3	26.5	29.1	25.6
	TG4	30.0	29.3	29.6
	TG5	34.2	30.1	27.0
LOW	MEAN ± SD	31.9 ± 5.1	29.2 ± 0.6	26.4 ± 1.2
	ATG1	35.5	27.3	27.8
	ATG2**	41.8	35.3	31.7
	ATG3	50.1	43.2	36.5
	ATG4	40.7	39.8	31.0
	ATG5	39.0	39.0	35.3
	MEAN ± SD	41.3 ± 4.8	37.3 ± 4.2	32.7 ± 3.1
	ITG1	28.8	31.9	31.7
	ITG2**	34.9	28.0	22.9
	ITG3	24.5	23.7	22.0
	ITG4	33.1	25.3	22.7
	ITG5	23.7	29.1	25.2
	MEAN ± SD	27.5 ± 3.7	27.5 ± 3.5	25.4 ± 3.3

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

Table 68 - F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output

Category	Group/Rank	Pre	Mid	Post
	CG1	17.42	17.12	16.91
	CG2**	17.32	17.43	17.03
	CG3	17.64	17.99	17.85
	CG4	17.03	16.42	16.82
	CG5	17.32	17.20	17.10
	MEAN ± SD	17.35 ± 0.22	17.18 ± 0.56	17.17 ± 0.40
	TG1	16.64	16.54	16.43
	TG2**	17.95	17.48	17.34
	TG3	16.48	16.41	16.09
	TG4	17.87	17.60	16.75
	TG5	16.70	15.77	15.09
HIGH	MEAN ± SD	16.92 ± 0.55	16.58 ± 0.66	16.09 ± 0.62
	ATG1	16.78	16.25	15.86
	ATG2*	17.63	-	-
	ATG3	16.16	16.61	15.81
	ATG4	16.60	16.31	16.15
	ATG5	17.82	17.23	16.79
	MEAN ± SD	16.84 ± 0.61	16.60 ± 0.39	16.15 ± 0.39
	ITG1	16.96	16.45	16.79
	ITG2**	18.11	18.04	16.90
	ITG3	17.30	16.61	16.38
	ITG4	17.20	17.26	16.48
	ITG5	16.90	16.47	16.11
	MEAN ± SD	17.09 ± 0.17	16.70 ± 0.33	16.44 ± 0.24
	CG1	17.57	18.02	17.78
	CG2**	17.49	17.65	17.72
	CG3	17.83	18.21	17.31
	CG4	17.71	17.49	17.53
	CG5	16.39	17.07	17.29
	MEAN ± SD	17.38 ± 0.58	17.70 ± 0.45	17.48 ± 0.20
	TG1	17.71	16.55	15.90
	TG2*	18.00	-	-
	TG3	16.43	17.00	15.99
	TG4	17.38	17.14	16.73
	TG5	17.66	17.17	16.58
LOW	MEAN ± SD	17.30 ± 0.52	16.97 ± 0.25	16.30 ± 0.36
	ATG1	17.75	16.77	16.54
	ATG2**	18.09	17.39	16.87
	ATG3	18.35	18.03	17.09
	ATG4	17.95	17.88	16.83
	ATG5	17.51	17.50	16.79
	MEAN ± SD	17.89 ± 0.31	17.55 ± 0.49	16.81 ± 0.20
	ITG1	17.30	17.47	17.28
	ITG2**	17.77	17.02	16.11
	ITG3	16.25	16.06	15.60
	ITG4	17.51	16.62	15.99
	ITG5	15.84	16.57	15.83
	MEAN ± SD	16.73 ± 0.70	16.68 ± 0.51	16.18 ± 0.65

* - Subject dropped out of the study

** - Subject whose data was excluded for the statistical analysis

APPENDIX D

SUMMARIES OF ANALYSES OF VARIANCE

Table 69-Summary of Analysis of Variance: Age of High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.52562500E+03	0.52562500E+03	1.	15.29	0.000
ERROR	0.13063516E+04	0.34377670E+02	38.		

Table 70- Summary of Analysis of Variance: Height of High and Low Fit Subjects

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.13000000E+02	0.13000000E+02	1.	0.37	0.545
ERROR	0.13270000E+04	0.34921051E+02	38.		

Table 71- Summary of Analysis of Variance: Weight of High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.22793750E+03	0.22793750E+03	1.	2.75	0.106
ERROR	0.31551875E+04	0.83031250E+02	38.		

Table 72- Summary of Analysis of Variance: Percent Body Fat of High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.40831641E+03	0.40831641E+03	1.	12.75	0.001
ERROR	0.12173125E+04	0.32034531E+02	38.		

Table 73- Summary of Analysis of Variance: Pre Training Absolute Maximum Oxygen Consumption of the High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.37624320E+07	0.37624320E+07	1.	21.41	0.000
ERROR	0.66772480E+07	0.17571700E+06	38.		

Table 74- Summary of Analysis of Variance: Pre Training Relative Maximum Oxygen Consumption of the High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.10547500E+04	0.10547500E+04	1.	75.05	0.000
ERROR	0.53406250E+03	0.14054276E+02	38.		

Table 75- Summary of Analysis of Variance:
Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of the High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.86316800E+06	0.86316800E+06	1.	12.77	0.001
ERROR	0.25691840E+07	0.67610063E+05	38.		

Table 76- Summary of Analysis of Variance:
Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of the High and Low Fit Categories

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.24899219E+03	0.24899219E+03	1.	23.87	0.000
ERROR	0.39632031E+03	0.10429482E+02	38.		

Table 77- Summary of Analysis of Variance:
Pre Training Relative Maximum Oxygen Consumption of Treatment Groups in the High Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.14808594E+02	0.49361973E+01	3.	0.27	0.844
ERROR	0.28981250E+03	0.18113281E+02	16.		

Table 78- Summary of Analysis of Variance:
Pre Training Relative Maximum Oxygen Consumption of Treatment Groups in the Low Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.58046875E+01	0.19348955E+01	3.	0.14	0.935
ERROR	0.22342188E+03	0.13963867E+02	16.		

Table 79- Summary of Analysis of Variance:
Pre Training Absolute Maximum Oxygen Consumption of Treatment Groups in the High Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.41939200E+06	0.13979731E+06	3.	0.65	0.594
ERROR	0.34365440E+07	0.21478400E+06	16.		

Table 80- Summary of Analysis of Variance:
Pre Training Absolute Maximum Oxygen Consumption of Treatment Groups in the Low Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.67550400E+06	0.22516800E+06	3.	1.68	0.211
ERROR	0.21456640E+07	0.13410400E+06	16.		

Table 81- Summary of Analysis of Variance: Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the High Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.20515625E+02	0.68385410E+01	3.	0.47	0.708
ERROR	0.23307422E+03	0.14567139E+02	16.		

Table 82- Summary of Analysis of Variance: Pre Training Relative Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the Low Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.11953125E+02	0.39843750E+01	3.	0.49	0.691
ERROR	0.12891406E+03	0.80571289E+01	16.		

Table 83- Summary of Analysis of Variance: Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the High Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.29201600E+06	0.97338625E+05	3.	1.15	0.361
ERROR	0.13591360E+07	0.84946000E+05	16.		

Table 84- Summary of Analysis of Variance: Pre Training Absolute Oxygen Consumption at the Anaerobic Threshold of Treatment Groups in the Low Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.31616000E+06	0.10538663E+06	3.	2.80	0.073
ERROR	0.60190400E+06	0.37619000E+05	16.		

Table 85- Summary of Analysis of Variance: Pre Training Power Output at the Anaerobic Threshold of Treatment Groups in the High Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.12150000E+06	0.40500000E+05	3.	2.00	0.155
ERROR	0.32400000E+06	0.20250000E+05	16.		

Table 86- Summary of Analysis of Variance: Pre Training Power Output at the Anaerobic Threshold of Treatment Groups in the Low Fit Category

ANALYSIS OF VARIANCE

SOURCE	SS	MS	DF	F	P
GROUPS	0.32400000E+05	0.10800000E+05	3.	0.53	0.666
ERROR	0.32400000E+06	0.20250000E+05	16.		

Table 87

Critical 'F' Ratios for Significance on the Analysis of Variance and Greenhouse-Geiser Conservative Test

	ANOVA		CONSERVATIVE TEST	
Term	DF (num,den)	Critical 'F' Ratio	DF (num,den)	Critical 'F' Ratio
Main Effect of C	2,48	3.19	1,24	4.26
AC Interaction	2,48	3.19	1,24	4.26
BC Interaction	6,48	2.30	3,24	3.01
ABC Interaction	6,48	2.30	3,24	3.01

Table 88- Summary of Analysis of Variance:
Power Output at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	4189952.0	31			
A	437248.00	1	437248.00	4.29	0.049
B	1006848.0	3	335616.00	3.29	0.038
AB	300032.00	3	100010.63	0.98	0.418
SUBJ W GROUP	2445824.0	24	101909.31		
WITHIN SUBJ	2721024.0	64			
C	1822976.0	2	911488.00	128.69	0.000
AC	2048.0000	2	1024.0000	0.14	0.866
BC	517888.00	6	86314.625	12.19	0.000
ABC	38144.000	6	6357.3320	0.90	0.504
C X SUBJ W G	339968.00	48	7082.6641		

Table 89- Summary of Analysis of Variance:
Time at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	130.85156	31			
A	13.128906	1	13.128906	4.36	0.048
B	40.425781	3	13.475260	4.48	0.012
AB	5.0273438	3	1.6757813	0.56	0.649
SUBJ W GROUP	72.269531	24	3.0112305		
WITHIN SUBJ	83.835938	64			
C	55.382813	2	27.691406	129.14	0.000
AC	0.35156250E-01	2	0.17578125E-01	0.08	0.921
BC	15.972656	6	2.6621094	12.41	0.000
ABC	2.1523438	6	0.35872394	1.67	0.148
C X SUBJ W G	10.292969	48	0.21443683		

Table 90- Summary of Analysis of Variance:
Ventilation Volume at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	0.32243712E+11	31			
A	0.10202644E+10	1	0.10202644E+10	0.93	0.345
B	0.27483177E+10	3	0.91610573E+09	0.83	0.488
AB	0.21065892E+10	3	0.70219622E+09	0.64	0.597
SUBJ W GROUP	0.26368541E+11	24	0.10986890E+10		
WITHIN SUBJ	0.18559795E+11	64			
C	0.77563167E+10	2	0.38781583E+10	23.50	0.000
AC	0.28730982E+09	2	0.14365491E+09	0.87	0.425
BC	0.20845691E+10	6	0.34742810E+09	2.11	0.070
ABC	0.51065651E+09	6	85109408.	0.52	0.793
C X SUBJ W G	0.79209431E+10	48	0.16501965E+09		

Table 91- Summary of Analysis of Variance:
Absolute Oxygen Consumption at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	22868480.	31			
A	6419456.0	1	6419456.0	13.81	0.001
B	3420416.0	3	1140138.0	2.45	0.088
AB	1868544.0	3	622848.00	1.34	0.285
SUBJ W GROUP	11160064.	24	465002.63		
WITHIN SUBJ	4926976.0	64			
C	2308352.0	2	1154176.0	39.61	0.000
AC	364288.00	2	182144.00	6.25	0.004
BC	773888.00	6	128981.31	4.43	0.001
ABC	81920.000	6	13653.332	0.47	0.828
C X SUBJ W G	1398528.0	48	29136.000		

Table 92- Summary of Analysis of Variance:
Relative Oxygen Consumption at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	3037.1250	31			
A	1709.5000	1	1709.5000	35.43	0.000
B	152.68750	3	50.895828	1.05	0.387
AB	17.000000	3	5.6666660	0.12	0.949
SUBJ W GROUP	1157.9375	24	48.247391		
WITHIN SUBJ	875.43750	64			
C	436.81250	2	218.40625	44.79	0.000
AC	61.500000	2	30.750000	6.31	0.004
BC	124.93750	6	20.822906	4.27	0.002
ABC	18.125000	6	3.0208330	0.62	0.714
C X SUBJ W G	234.06250	48	4.8763018		

Table 93- Summary of Analysis of Variance:
$\dot{V}_E/\dot{V}O_2$ Ratio at the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	2140.0000	31			
A	384.37500	1	384.37500	8.43	0.008
B	297.87500	3	99.291656	2.18	0.117
AB	363.87500	3	121.29166	2.66	0.071
SUBJ W GROUP	1093.8750	24	45.578125		
WITHIN SUBJ	944.37500	64			
C	65.062500	2	32.531250	2.12	0.132
AC	5.4375000	2	2.7187500	0.18	0.839
BC	40.437500	6	6.7395830	0.44	0.850
ABC	95.187500	6	15.864583	1.03	0.417
C X SUBJ W G	738.25000	48	15.380208		

Table 94- Summary of Analysis of Variance:
Power Output at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	2158672.0	31			
A	437408.00	1	437408.00	6.87	0.015
B	93152.000	3	31050.664	0.49	0.694
AB	99888.000	3	33296.000	0.52	0.671
SUBJ W GROUP	1528224.0	24	63676.000		
WITHIN SUBJ	626400.00	64			
C	186992.00	2	93496.000	13.41	0.000
AC	14160.000	2	7080.0000	1.02	0.370
BC	26304.000	6	4384.0000	0.63	0.707
ABC	64160.000	6	10693.332	1.53	0.188
C X SUBJ W G	334784.00	48	6974.6641		

Table 95- Summary of Analysis of Variance:
Time at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	63.643311	31			
A	11.690186	1	11.690186	6.09	0.021
B	2.7788086	3	0.92626953	0.48	0.697
AB	3.1118164	3	1.0372715	0.54	0.659
SUBJ W GROUP	46.062500	24	1.9192705		
WITHIN SUBJ	20.666748	64			
C	7.3803711	2	3.6901855	16.67	0.000
AC	0.47387695	2	0.23693848	1.07	0.351
BC	0.61962891	6	0.10327148	0.47	0.830
ABC	1.5690918	6	0.26151526	1.18	0.332
C X SUBJ W G	10.625000	48	0.22135413		

Table 96- Summary of Analysis of Variance:
Ventilation Volume at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	0.47967109E+10	31			
A	0.62121574E+09	1	0.62121574E+09	4.55	0.043
B	0.45403341E+09	3	0.15134446E+09	1.11	0.365
AB	0.44217139E+09	3	0.14739046E+09	1.08	0.377
SUBJ W GROUP	0.32792904E+10	24	0.13663709E+09		
WITHIN SUBJ	0.12082217E+10	64			
C	0.30841242E+09	2	0.15420621E+09	10.74	0.000
AC	8323072.0	2	4161536.0	0.29	0.750
BC	91619328.	6	15269888.	1.06	0.397
ABC	0.11075584E+09	6	18459296.	1.29	0.282
C X SUBJ W G	0.68911104E+09	48	14356480.		

Table 97- Summary of Analysis of Variance:
Absolute Oxygen Consumption at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	7756464.0	31			
A	1797632.0	1	1797632.0	9.74	0.005
B	1004288.0	3	334762.63	1.81	0.172
AB	522896.00	3	174298.63	0.94	0.435
SUBJ W GROUP	4431648.0	24	184652.00		
WITHIN SUBJ	1472624.0	64			
C	278832.00	2	139416.00	7.94	0.001
AC	42432.000	2	21216.000	1.21	0.308
BC	225536.00	6	37589.332	2.14	0.066
ABC	82896.000	6	13816.000	0.79	0.585
C X SUBJ W G	843152.00	48	17565.664		

Table 98- Summary of Analysis of Variance:
Relative Oxygen Consumption at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	1277.0000	31			
A	466.39453	1	466.39453	15.67	0.001
B	68.289063	3	22.763016	0.76	0.525
AB	27.968750	3	9.3229160	0.31	0.816
SUBJ W GROUP	714.34766	24	29.764481		
WITHIN SUBJ	268.21484	64			
C	53.105469	2	26.552734	8.54	0.001
AC	6.5117188	2	3.2558594	1.05	0.359
BC	39.867188	6	6.6445313	2.14	0.066
ABC	19.515625	6	3.2526035	1.05	0.408
C X SUBJ W G	149.23047	48	3.1089678		

Table 99- Summary of Analysis of Variance:
$\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One

SOURCE	SS	DF	MS	F	P
BET SUBJ	365.15625	31			
A	34.906250	1	34.906250	3.36	0.079
B	17.218750	3	5.7395830	0.55	0.652
AB	63.480469	3	21.160156	2.04	0.136
SUBJ W GROUP	249.55078	24	10.397949		
WITHIN SUBJ	159.45703	64			
C	8.0546875	2	4.0273438	1.50	0.234
AC	2.8632813	2	1.4316406	0.53	0.590
BC	10.523438	6	1.7539063	0.65	0.687
ABC	9.1328125	6	1.5221348	0.57	0.755
C X SUBJ W G	128.91406	48	2.6857090		

Table 100-Summary of Analysis of Variance: Power Output at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	5653296.0	31			
A	912592.00	1	912592.00	6.30	0.019
B	1058384.0	3	352794.63	2.44	0.089
AB	205200.00	3	68400.000	0.47	0.705
SUBJ W GROUP	3477120.0	24	144880.00		
WITHIN SUBJ	2765312.0	64			
C	1268272.0	2	634136.00	45.41	0.000
AC	720.00000	2	360.00000	0.03	0.975
BC	737808.00	6	122968.00	8.81	0.000
ABC	88304.000	6	14717.332	1.05	0.403
C X SUBJ W G	670336.00	48	13965.332		

Table 101- Summary of Analysis of Variance: Time at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	168.32422	31			
A	26.042969	1	26.042969	5.86	0.023
B	30.304688	3	10.101563	2.27	0.106
AB	5.3945313	3	1.7981768	0.40	0.751
SUBJ W GROUP	106.58203	24	4.4409180		
WITHIN SUBJ	87.667969	64			
C	43.226563	2	21.613281	57.50	0.000
AC	0.22265625	2	0.11132813	0.30	0.745
BC	23.210938	6	3.8684893	10.29	0.000
ABC	2.9648438	6	0.49414063	1.31	0.269
C X SUBJ W G	18.042969	48	0.37589514		

Table 102- Summary of Analysis of Variance: Ventilation Volume at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	0.22488678E+11	31			
A	0.23098819E+10	1	0.23098819E+10	3.57	0.071
B	0.31562793E+10	3	0.10520929E+10	1.62	0.210
AB	0.14727250E+10	3	0.49090816E+09	0.76	0.529
SUBJ W GROUP	0.15549792E+11	24	0.64790784E+09		
WITHIN SUBJ	0.10968564E+11	64			
C	0.48655237E+10	2	0.24327619E+10	34.74	0.000
AC	5111808.0	2	2555904.0	0.04	0.964
BC	0.24243732E+10	6	0.40406221E+09	5.77	0.000
ABC	0.31182029E+09	6	51970048.	0.74	0.618
C X SUBJ W G	0.33617347E+10	48	70036128.		

Table 103- Summary of Analysis of Variance: Absolute Oxygen Consumption at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	24079360.	31			
A	5572864.0	1	5572864.0	10.08	0.004
B	4118784.0	3	1372928.0	2.48	0.085
AB	1112832.0	3	370944.00	0.67	0.578
SUBJ W GROUP	13274880.	24	553120.00		
WITHIN SUBJ	6467584.0	64			
C	2732032.0	2	1366016.0	35.45	0.000
AC	23040.000	2	11520.000	0.30	0.743
BC	1673728.0	6	278954.63	7.24	0.000
ABC	189184.00	6	31530.664	0.82	0.561
C X SUBJ W G	1849600.0	48	38533.332		

Table 104- Summary of Analysis of Variance: Relative Oxygen Consumption at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	4081.7500	31			
A	1495.4375	1	1495.4375	16.66	0.000
B	358.62500	3	119.54166	1.33	0.287
AB	73.312500	3	24.437500	0.27	0.845
SUBJ W GROUP	2154.3750	24	89.765625		
WITHIN SUBJ	1193.6250	64			
C	482.87500	2	241.43750	33.20	0.000
AC	2.3750000	2	1.1875000	0.16	0.850
BC	331.37500	6	55.229156	7.59	0.000
ABC	27.937500	6	4.6562500	0.64	0.697
C X SUBJ W G	349.06250	48	7.2721348		

Table 105- Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two

SOURCE	SS	DF	MS	F	P
BET SUBJ	567.00000	31			
A	61.875000	1	61.875000	3.93	0.059
B	20.250000	3	6.7500000	0.43	0.734
AB	106.87500	3	35.625000	2.26	0.107
SUBJ W GROUP	378.00000	24	15.750000		
WITHIN SUBJ	375.75000	64			
C	75.875000	2	37.937500	7.51	0.001
AC	6.6875000	2	3.3437500	0.66	0.520
BC	40.625000	6	6.7708330	1.34	0.258
ABC	10.125000	6	1.6875000	0.33	0.916
C X SUBJ W G	242.43750	48	5.0507813		

Table 106- Summary of Analysis of Variance: Power Output at Threshold One Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	4652.7500	31			
A	390.43750	1	390.43750	2.33	0.140
B	52.375000	3	17.458328	0.10	0.957
AB	187.31250	3	62.437500	0.37	0.774
SUBJ W GROUP	4022.6250	24	167.60938		
WITHIN SUBJ	1721.1875	64			
C	24.687500	2	12.343750	0.48	0.619
AC	15.437500	2	7.7187500	0.30	0.740
BC	273.43750	6	45.572906	1.79	0.122
ABC	183.37500	6	30.562500	1.20	0.323
C X SUBJ W G	1224.2500	48	25.505203		

Table 107- Summary of Analysis of Variance: Time at Threshold One Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	3878.6250	31			
A	248.62500	1	248.62500	1.75	0.198
B	97.687500	3	32.562500	0.23	0.875
AB	122.81250	3	40.937500	0.29	0.833
SUBJ W GROUP	3409.5000	24	142.06250		
WITHIN SUBJ	1432.3125	64			
C	43.375000	2	21.687500	1.07	0.352
AC	37.750000	2	18.875000	0.93	0.402
BC	184.68750	6	30.781250	1.52	0.193
ABC	191.37500	6	31.895828	1.57	0.176
C X SUBJ W G	975.12500	48	20.315094		

Table 108- Summary of Analysis of Variance: Ventilation Volume at Threshold One Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	1893.3750	31			
A	94.625000	1	94.625000	1.43	0.244
B	154.43750	3	51.479156	0.78	0.518
AB	53.937500	3	17.979156	0.27	0.845
SUBJ W GROUP	1590.3750	24	66.265625		
WITHIN SUBJ	1119.9375	64			
C	54.812500	2	27.406250	1.73	0.188
AC	8.0625000	2	4.0312500	0.25	0.776
BC	148.50000	6	24.750000	1.56	0.179
ABC	147.68750	6	24.614578	1.55	0.182
C X SUBJ W G	760.87500	48	15.851563		

Table 109- Summary of Analysis of Variance:
Oxygen Consumption at Threshold One Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	3142.9375	31			
A	16.500000	1	16.500000	0.14	0.713
B	30.375000	3	10.125000	0.08	0.968
AB	231.00000	3	77.000000	0.65	0.594
SUBJ W GROUP	2865.0625	24	119.37759		
WITHIN SUBJ	1297.9375	64			
C	43.812500	2	21.906250	1.24	0.300
AC	7.8125000	2	3.9062500	0.22	0.803
BC	263.31250	6	43.885406	2.47	0.036
ABC	131.68750	6	21.947906	1.24	0.304
C X SUBJ W G	851.31250	48	17.735672		

Table 110- Summary of Analysis of Variance:
$\dot{V}_E/\dot{V}O_2$ Ratio at Threshold One Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	2555.8125	31			
A	236.12500	1	236.12500	3.17	0.088
B	344.25000	3	114.75000	1.54	0.230
AB	188.43750	3	62.812500	0.84	0.483
SUBJ W GROUP	1787.0000	24	74.458328		
WITHIN SUBJ	2482.3125	64			
C	101.00000	2	50.500000	1.32	0.277
AC	5.5000000	2	2.7500000	0.07	0.931
BC	171.12500	6	28.520828	0.74	0.617
ABC	364.56250	6	60.760406	1.58	0.172
C X SUBJ W G	1840.1250	48	38.335938		

Table 111- Summary of Analysis of Variance:
Power Output at Threshold Two Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	8046.3125	31			
A	714.00000	1	714.00000	3.02	0.095
B	1451.4375	3	483.81250	2.05	0.134
AB	212.31250	3	70.770828	0.30	0.825
SUBJ W GROUP	5668.5625	24	236.19009		
WITHIN SUBJ	3419.3125	64			
C	128.87500	2	64.437500	1.25	0.296
AC	8.1875000	2	4.0937500	0.08	0.924
BC	603.00000	6	100.50000	1.95	0.092
ABC	201.37500	6	33.562500	0.65	0.690
C X SUBJ W G	2477.8750	48	51.622391		

Table 112- Summary of Analysis of Variance: Time at Threshold Two Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	7017.8125	31			
A	555.50000	1	555.50000	2.59	0.121
B	1103.5625	3	367.85400	1.72	0.190
AB	213.87500	3	71.291656	0.33	0.802
SUBJ W GROUP	5144.8750	24	214.36978		
WITHIN SUBJ	2825.1875	64			
C	120.12500	2	60.062500	1.57	0.219
AC	23.625000	2	11.812500	0.31	0.736
BC	665.87500	6	110.97916	2.90	0.017
ABC	176.62500	6	29.437500	0.77	0.598
C X SUBJ W G	1838.9375	48	38.311188		

Table 113- Summary of Analysis of Variance: Ventilation Volume at Threshold Two Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	8862.8750	31			
A	502.12500	1	502.12500	1.89	0.182
B	1232.7500	3	410.91650	1.55	0.228
AB	754.68750	3	251.56250	0.95	0.433
SUBJ W GROUP	6373.3125	24	265.55469		
WITHIN SUBJ	3630.5000	64			
C	181.62500	2	90.812500	2.03	0.143
AC	69.750000	2	34.875000	0.78	0.465
BC	851.00000	6	141.83333	3.16	0.011
ABC	377.00000	6	62.833328	1.40	0.233
C X SUBJ W G	2151.1250	48	44.815094		

Table 114- Summary of Analysis of Variance: Oxygen Consumption at Threshold Two Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	6721.1875	31			
A	259.81250	1	259.81250	1.19	0.285
B	1062.9375	3	354.31250	1.63	0.209
AB	173.56250	3	57.854156	0.27	0.849
SUBJ W GROUP	5224.8750	24	217.70313		
WITHIN SUBJ	3123.0625	64			
C	245.31250	2	122.65625	3.03	0.058
AC	73.562500	2	36.781250	0.91	0.410
BC	705.56250	6	117.59375	2.90	0.017
ABC	155.43750	6	25.906250	0.64	0.698
C X SUBJ W G	1943.1875	48	40.483063		

Table 115- Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at Threshold Two Expressed as a Percentage of the Maximum Exercise Capacity

SOURCE	SS	DF	MS	F	P
BET SUBJ	3853.8750	31			
A	175.50000	1	175.50000	1.59	0.219
B	335.25000	3	111.75000	1.01	0.404
AB	698.87500	3	232.95833	2.11	0.125
SUBJ W GROUP	2644.2500	24	110.17708		
WITHIN SUBJ	3099.9375	64			
C	29.000000	2	14.500000	0.30	0.742
AC	4.5000000	2	2.2500000	0.05	0.954
BC	427.62500	6	71.270828	1.48	0.206
ABC	323.87500	6	53.979156	1.12	0.365
C X SUBJ W G	2314.9375	48	48.227859		

Table 116- Summary of Analysis of Variance: Ventilation Volume at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	0.40160461E+11	31			
A	0.10632561E+10	1	0.10632561E+10	0.84	0.370
B	0.53781463E+10	3	0.17927153E+10	1.41	0.265
AB	0.31782339E+10	3	0.10594112E+10	0.83	0.489
SUBJ W GROUP	0.30540825E+11	24	0.12725343E+10		
WITHIN SUBJ	0.15120466E+11	64			
C	0.71670170E+10	2	0.35835085E+10	31.45	0.000
AC	0.28206694E+09	2	0.14103347E+09	1.24	0.299
BC	0.19272827E+10	6	0.32121370E+09	2.82	0.020
ABC	0.27472691E+09	6	45787808.	0.40	0.874
C X SUBJ W G	0.54693724E+10	48	0.11394525E+09		

Table 117- Summary of Analysis of Variance: Absolute Oxygen Consumption at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	21145344.	31			
A	6841088.0	1	6841088.0	13.76	0.001
B	914176.00	3	304725.31	0.61	0.613
AB	1462016.0	3	487338.63	0.98	0.418
SUBJ W GROUP	11928064.	24	497002.63		
WITHIN SUBJ	3050752.0	64			
C	623104.00	2	311552.00	8.37	0.001
AC	335872.00	2	167936.00	4.51	0.016
BC	157440.00	6	26240.000	0.71	0.647
ABC	148480.00	6	24746.664	0.67	0.678
C X SUBJ W G	1785856.0	48	37205.332		

Table 118- Summary of Analysis of Variance: Carbon Dioxide Production at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	36082432.	31			
A	10294016.	1	10294016.	11.99	0.002
B	2301952.0	3	767317.31	0.89	0.459
AB	2885120.0	3	961706.63	1.12	0.360
SUBJ W GROUP	20601344.	24	858389.31		
WITHIN SUBJ	4701440.0	64			
C	1542144.0	2	771072.00	17.56	0.000
AC	259840.00	2	129920.00	2.96	0.061
BC	596992.00	6	99498.625	2.27	0.053
ABC	194560.00	6	32426.664	0.74	0.621
C X SUBJ W G	2107904.0	48	43914.664		

Table 119- Summary of Analysis of Variance: $\dot{V}_E/\dot{V}O_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	2860.1250	31			
A	432.62500	1	432.62500	9.06	0.006
B	778.68750	3	259.56250	5.44	0.005
AB	503.31250	3	167.77083	3.52	0.030
SUBJ W GROUP	1145.5000	24	47.729156		
WITHIN SUBJ	1374.5000	64			
C	421.06250	2	210.53125	16.37	0.000
AC	27.625000	2	13.812500	1.07	0.350
BC	231.75000	6	38.625000	3.00	0.014
ABC	76.812500	6	12.802083	1.00	0.439
C X SUBJ W G	617.25000	48	12.859375		

Table 120- Summary of Analysis of Variance: $\dot{V}_E/\dot{V}CO_2$ Ratio at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	2359.9375	31			
A	342.75000	1	342.75000	8.50	0.008
B	561.93750	3	187.31250	4.64	0.011
AB	487.18750	3	162.39583	4.03	0.019
SUBJ W GROUP	968.06250	24	40.335938		
WITHIN SUBJ	732.50000	64			
C	209.18750	2	104.59375	12.77	0.000
AC	9.4375000	2	4.7187500	0.58	0.566
BC	76.937500	6	12.822916	1.57	0.178
ABC	43.750000	6	7.2916660	0.89	0.510
C X SUBJ W G	393.18750	48	8.1914063		

Table 121- Summary of Analysis of Variance: F_EO_2 at the Pre Training Maximum Exercise Capacity Power Output

SOURCE	SS	DF	MS	F	P
BET SUBJ	29.644531	31			
A	2.4375000	1	2.4375000	3.82	0.062
B	8.2617188	3	2.7539063	4.32	0.014
AB	3.6445313	3	1.2148438	1.91	0.156
SUBJ W GROUP	15.300781	24	0.63753253		
WITHIN SUBJ	13.683594	64			
C	6.1835938	2	3.0917969	29.59	0.000
AC	0.22656250	2	0.11328125	1.08	0.346
BC	1.9804688	6	0.33007813	3.16	0.011
ABC	0.27734375	6	0.46223957E-01	0.44	0.847
C X SUBJ W G	5.0156250	48	0.10449219		